Testing and Evaluation of a Portable Workzone Sign Support: FOIL Test Numbers 98F008 and 98F009

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Research and Development
Turner-Fairbank Highway Research Center
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FOREWORD

This report documents the results from two crash tests performed at the Federal Highway Administration's (FHWA) Federal Outdoor Impact Laboratory (FOIL) located at the Turner-Fairbank Highway Research Center (TFHRC) in McLean, Virginia. The purpose of the tests was to evaluate the safety performance of a portable work-zone sign trailer currently used by the State of Montana. The tests were also conducted to provide computer simulation engineers with electronic crash test data from a small car collision with a small portable sign support. Future improvements or modifications to the portable sign trailer may be tested by first using computer simulation before actual crash testing to evaluate the safety performance.

This report (FHWA-RD-98-183) contains test data, photographs taken with high-speed film, and a summary of the test results. The target test speed for these tests was 100 km/h.

This report will be of interest to all State departments of transportation, FHWA headquarters, region and division personnel, and highway safety researchers interested in the crashworthiness of roadside safety hardware.

A. George Ostensen
A. George Ostensen, Director
Office of Safety and Traffic
Operations Research and Development

NOTICE

Technical Report Documentation Page

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16. Abstract
This report contains the test procedures, test setup, and test results from two crash tests performed at the Federal Highway Administration's (FHWA) Federal Outdoor Impact Laboratory (FOIL) located at the Turner-Fairbank Highway Research Center (TFHRC) in McLean, Virginia. The purpose of the tests was to evaluate the safety performance of a portable work-zone sign trailer currently used by the State of Montana. The tests were also conducted to provide computer simulation engineers with electronic crash test data from a small car collision with a small portable sign support. Two portable sign trailers were delivered to the FOIL to be tested. The vehicles used for the two sign trailer tests were a 1990 and a 1991 Ford Festiva. The test vehicle in each test had one anthropomorphic dummy placed in the driver seat. The uninstrumented dummy was used for ballast only, to add a realistic shifting mass that can be critical when evaluating post-collision vehicle stability. The target test speed for each test was 100 km/h. The FHWA will use this report and other information to determine the sign support's level of safety.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: Volumes greater than 1000 l shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

(Revised September 1993)

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SCOPE

This report documents the results from two crash tests performed at the Federal Highway Administration's (FHWA) Federal Outdoor Impact Laboratory (FOIL) located at the Turner-Fairbank Highway Research Center (TFHRC) in McLean, Virginia. The crash tests were conducted in accordance with the guidelines outlined in the National Cooperative Highway Research Program (NCHRP) Report 350.[1] The purpose of the tests was to evaluate the safety performance of a portable work-zone sign trailer currently used by the State of Montana. The tests were also conducted to provide computer simulation engineers with electronic crash test data from a small car collision with a small portable sign support. Future improvements or modifications to the portable sign trailer may be tested by first using computer simulation before actual crash testing to evaluate the safety performance. The safety performance evaluation will be based on criteria set forth in NCHRP Report 350. The evaluation criteria specify, in part, that there can be no occupant compartment intrusion by any sign support members, that the occupant impact velocity (OIV) must be less than 5 m/s, that the vehicle must maintain its stability, and that the vehicle and sign support cannot pose a hazard to other traffic. This report alone does not "pass or fail" the sign support trailer. The report documents whether or not the sign trailer met or did not meet the safety performance criteria outlined in NCHRP Report 350. The FHWA will use this report and other information to determine the sign support's level of safety.

Two portable sign trailers were delivered to the FOIL to be tested. The vehicles used for the two sign trailer tests were a 1990 and a 1991 Ford Festiva. The target inertial weight of the Ford Festivas was 820 kg. The target test speed for each test was 100 km/h.

MATRIX

Two sign trailers were tested to evaluate the sign supports' safety performance. The standard test matrix for work-zone traffic control devices outlined in NCHRP Report 350 requires two crash tests, one at low speed and one at high speed, using a small vehicle (test designations 3-70 and 3-71). However, NCHRP Report 350 states that the low-speed test, test 3-70, may be omitted if it is determined that the high-speed test, test 3-71, is more critical. The portable sign trailer weighed 113 kg, which is relatively heavy in proportion to the test vehicle (14 percent of the vehicle weight). However, the sign support was mounted on a trailer with wheels and tires. It was decided that the sign trailer would move easily when struck by a Festiva at low speed and it was also decided that the sign trailer may not move out of the path of the vehicle quickly enough during a high-speed collision and would, therefore, induce instability in the test vehicle. The high-speed test was considered more critical; therefore, test 3-70 was not conducted. Although test 3-70 was omitted, two crash tests were conducted. The State of Montana currently uses the sign trailer in two orientations. The sign trailer was tested in each orientation. The first orientation tested was with the sign panel facing the test vehicle but with the trailer hitch or tongue pointing to the right of the vehicle's trajectory (i.e., the trailer axle was parallel with the centerline of the test vehicle). This orientation is used most often. The second orientation tested was with the sign panel facing the vehicle with the trailer hitch pointing downrange away from the test vehicle (i.e., the trailer axle was perpendicular to the centerline of the test vehicle). In each test, regardless of sign orientation, the test vehicle centerline was aligned with the sign post mounted vertically at the center of the trailer's axle.

The test vehicle in each test had one anthropomorphic dummy placed in the driver seat. The uninstrumented dummy was used for ballast only, to add a realistic shifting mass that can be critical when evaluating post-collision vehicle stability. Table 1 is the test matrix for testing the portable sign trailer.

Table 1. Test matrix for portable sign trailer tests.

Test Number	Test Date	Test Vehicle	NCHRP Test	Test Speed	Impact Angle	Impact Point
98F008	5-28-98	1990 Ford Festiva	3-71	100 km/h	0°	On trailer tire
98F009	6-04-98	1991 Ford Festiva	3-71	100 km/h	0°	Between tires, on sign post

TEST VEHICLE

The test vehicles used for these two tests were Ford Festiva two-door hatchbacks with five-speed manual transmissions. Prior to testing, all of the vehicles' fluids were drained and certain vehicle components were removed to allow for the installation of data acquisition equipment, sensors, a remote brake system, and guidance system components. Nothing was removed from the test vehicles' engine compartment. The target inertial test weight of the vehicles was 820 kg. An anthropomorphic dummy was placed in the driver seat as ballast to observe occupant kinematics. With the dummy, the total target test vehicle weight was 900 kg. Table 2 lists some physical properties of both vehicles. Additional physical properties of the test vehicles are shown in figures 1 and 2.

DATE: 5-28-98 TEST NO: 98F008 TIRE PRESSURE: 35 psi MAKE: FORD

MODEL: FESTIVA YEAR: 1990 ODOMETER: GVW:

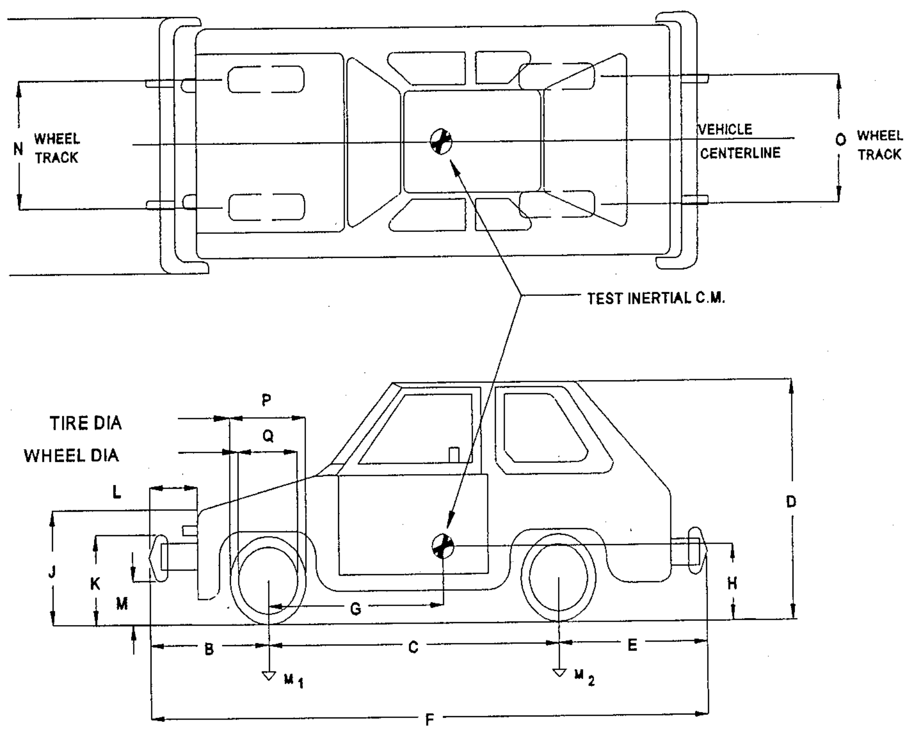
TIRE SIZE: VIN NUMBER: KNJPT06HOL6132158 TREAD TYPE:

MASS DISTRIBUTION: CURB: LF 260 LF 252 LR 139 RR 145

TEST INERTIAL: LF 259 RF 260 LR 153 RR 146

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST:

NONE



ENGINE TYPE: 1.3L 4 CYL.

ENGINE CID:

TRANSMISSION TYPE:

___AUTO

X MANUAL

OPTIONAL EQUIPMENT:

AIR CONDITIONING

DUMMY DATA:

TYPE: SID

MASS: 68 kg

SEAT POSITION: DRIVER

GEOMETRY

A 1556	E 521	J 953	N 1397	R
B 673	F 3531	K 546	O 1403	S
C 2305	G 876	L 102	P 533	T
D 1454	H 533	M 406	Q 305	U

MASS	CURB	TEST INERTIAL	GROSS STATIC
M_1	512	519	
M_2	283	299	
M_T	795	818	

Figure 1. Vehicle properties for test 98F008.

DATE: 6-4-98 TEST NO: 98F009 TIRE PRESSURE: ______ MAKE: FORD

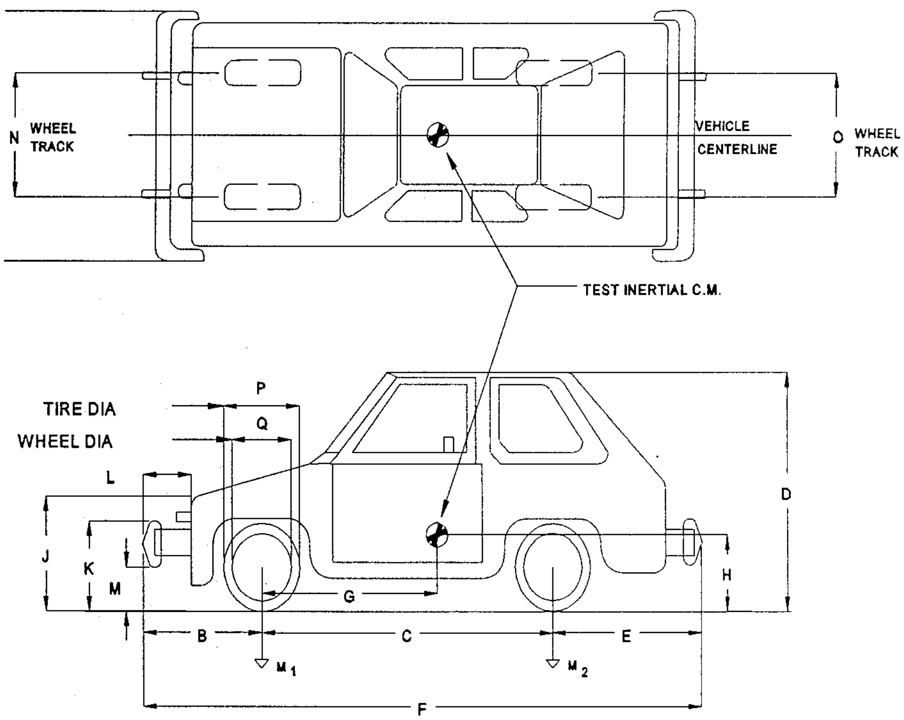
MODEL: FESTIVA YEAR: 1991 ODOMETER: ______ GVW: ______

TIRE SIZE: ______ VIN NUMBER: KNJPTO5H6M6138114 TREAD TYPE: ______

MASS DISTRIBUTION: CURB: LF 256 RF 244 LR 147 RR 139

TEST INERTIAL: LF 258 RF 254 LR 158 RR 148

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST:



ENGINE TYPE: 1.3l 4 CYL.

ENGINE CID: ______

TRANSMISSION TYPE:

___AUTO

___MANUAL

OPTIONAL EQUIPMENT:

DUMMY DATA:

TYPE: SID

MASS: 68 kg

SEAT POSITION: DRIVER

GEOMETRY

A 1556	E 521	J 953	N 1397	R
B 673	F 3531	K 546	O 1403	S
C 2305	G 876	L 102	P 533	T
D 1454	H 533	M 406	Q 305	U

MASS	CURB	TEST INERTIAL	GROSS STATIC
M_1	500	512	
M_2	286	306	
M_T	786	818	

Figure 2. Vehicle properties for test 98F009.

Table 2. Physical properties of the test vehicles.					
Test Number	**Vehicle**	**Inertial Weight**	**Inertial Properties ($kg \bullet m^2$)**		
			Pitch	**Roll**	**Yaw**
98F008	1990 Ford Festiva	819 kg	909.5	288.6	1098.3
98F009	1991 Ford Festiva	818 kg	858.7	224.8	1042.7

DEVICE TESTED

Two tests were conducted on the work-zone portable sign trailer. The portable sign trailer consisted of a 75-mm box tube axle 1525-mm long. Welded to each end of the box tube was a small block with a spindle attached. A wheel-tire assembly was mounted to each spindle. Two P205/75 R14 tires were delivered on the sign trailer. At the center of the axle, a 50-mm box sleeve was welded vertically to accept a 50-mm steel tube sign post. A 1920-mm tongue was attached to the axle to allow for easy towing of the sign support. The tongue and sign post sleeve were reinforced with 50-mm steel angle braces. A 50-mm ball hitch was also mounted to the axle (opposite of the tongue) to allow for tandem towing of multiple sign trailers. The vertical sign post was inserted into the trailer sleeve and a 1675-mm square aluminum sign panel was attached to the sign post. The sign panel was attached using four hardware quality 8-mm bolts with a flat washer on each side and fastened with a 8-mm nut. All sign materials, excluding the tires and sign panel, were fabricated from ASTM A36 steel. The total weight of the portable sign trailer with sign post was 113 kg. The tires were inflated to 220 kPa prior to testing. Figure 3 is a sketch of the portable sign trailer as tested. Figure 4 is the design drawing supplied by the Montana Department of Transportation (DOT).

The signs were tested in two orientations. The first orientation aligned the centerline of the test vehicle with the longitudinal centerline of the trailer axle with the tongue of the trailer pointing to the right of the vehicle trajectory. The sign panel was facing the incoming vehicle. The other orientation involved rotating the sign trailer 90° (counterclockwise) from the first position. The tongue of the trailer was pointing downrange from the test vehicle and in line with the vehicle trajectory. The sign post was rotated 90° in the sleeve to face the test vehicle.

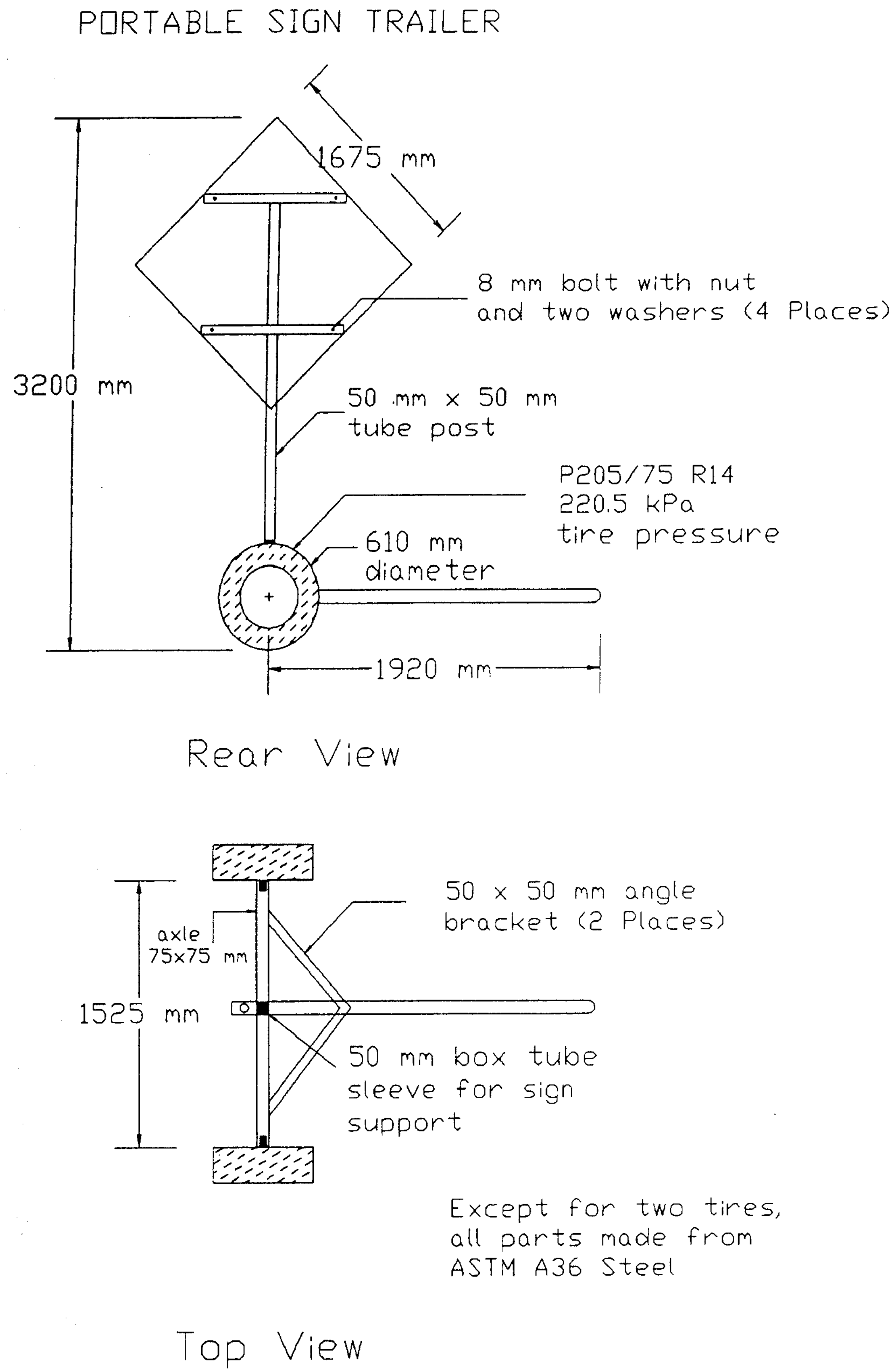


Figure 3. Sketch of portable sign trailer as tested.

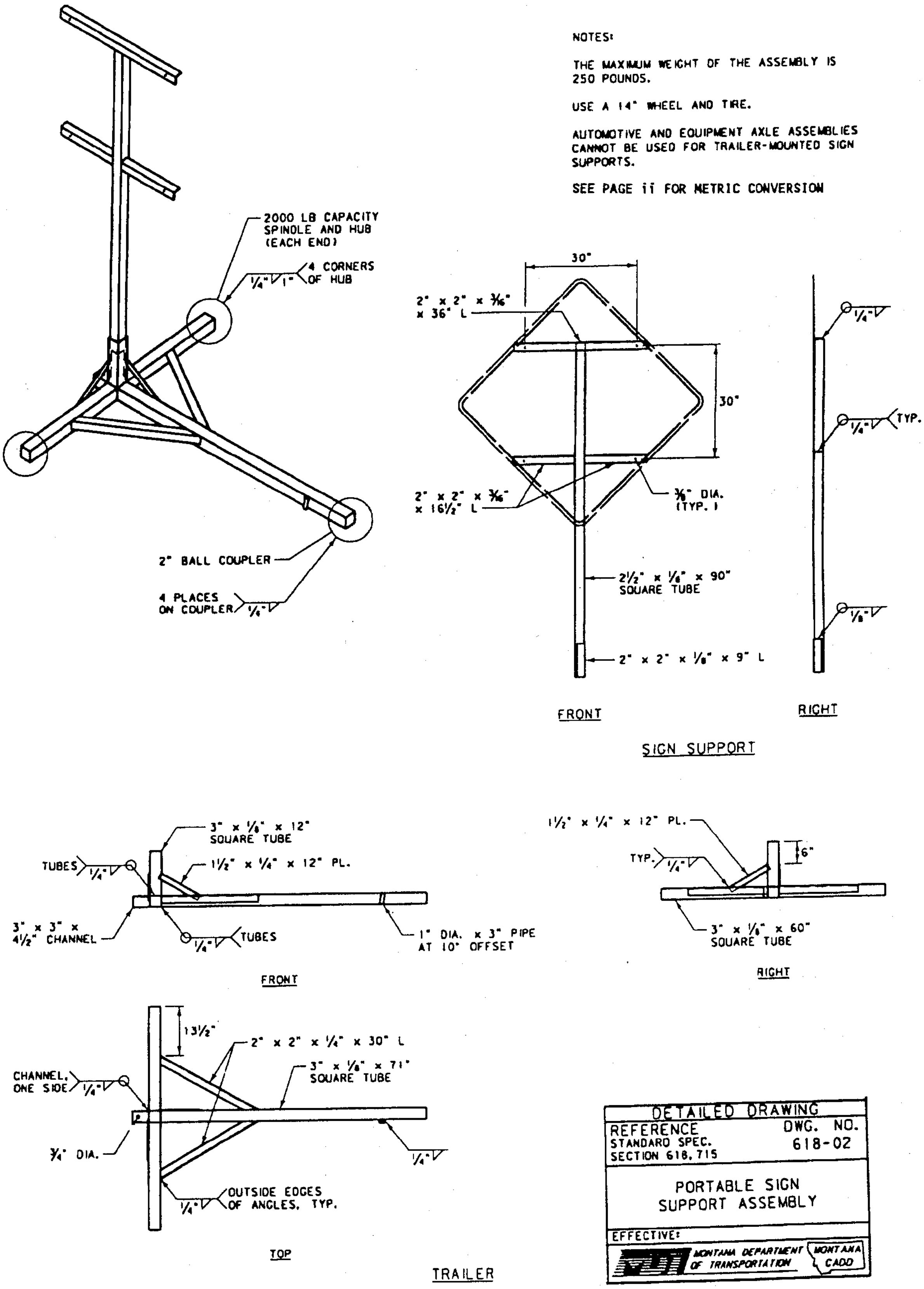


Figure 4. Design drawing of portable sign trailer.

DATA ACQUISITION AND INSTRUMENTATION

For each of the tests, speed trap, accelerometer, and high-speed film data were collected to evaluate the safety performance of the portable work-zone sign trailer. Instrumentation was added to the test vehicle in accordance with Federal Motor Vehicle Safety Standard (FMVSS) 208.[2] The added accelerometers will assist computer simulation engineers to model specific vehicle components during a collision with a small sign support structure.

a. Speed Trap. The speed trap was used to determine the vehicles' speed just prior to contact with the portable sign trailer. The center of the speed trap was placed approximately 2 m before the portable sign trailer. The speed trap consisted of a set of five contact switches fastened to the runway at 0.3-m intervals. As the vehicles passed over the switches, electronic pulses were recorded on analog tape.

b. Transducer Data. The instrumentation used consisted of a triaxial cg accelerometer and a triaxial rate transducer at the vehicle's cg. In addition, the Ford Festivas were instrumented as described in FMVSS 208. The data from the transducers were recorded by two data acquisition systems, the ODAS III on-board system and an umbilical cable tape recorder system. Table 3 describes the FMVSS 208 instrumentation including accelerometer locations. The location coordinates were referenced from the right front wheel hub, which was 255 mm above ground.

The ODAS III is a self-contained system. The output from the sensors was pre-filtered, digitally sampled, and digitally stored within the ODAS units mounted directly to the test vehicle inside the occupant compartment. The ODAS units are factory set with a 4000 Hz analog pre-filter and a digital sampling rate of 12,500 Hz. FMVSS 208 accelerometer and rate transducer data were collected via the ODAS III system.

The FOIL umbilical cable system utilizes a 90-m cable between vehicle transducers or other sensors and a rack of signal conditioning amplifiers. The output from the amplifiers was recorded on 25-mm magnetic tape via a Honeywell 5600E tape recorder. After the test, the tape was played back through anti-ailiasing filters, then input to a Data Translation analog-to-digital converter (ADC). The sample rate was set to 5000 Hz. The umbilical cable system recorded cg acceleration data, the speed trap signals, and a 1 kHz reference used to verify tape recorder operation.

Table 3. Instrumentation used for the portable sign trailer tests.			
Location	**Data**	**Full Scale**	**(X,Y,Z) position* (mm)**
1	Top of motor	2000 g	+140, 815, 520
2	Bottom of motor	2000 g	+125, 850, -50
3	Right control arm	2000 g	+103, 152, -25
4	Left control arm	2000 g	+103, 1435, -25
5	Top of instrument	2000 g	-495, 812, 673
CG	Tri-axial rate transducer, pitch, roll, yaw	500 deg/s	-813, 790, 115
CG	Longitudinal	100 g	-813, 790, 115
CG	Lateral acceleration	100 g	-813, 790, 115
CG	Vertical acceleration	100 g	-813, 790, 115
CG	Longitudinal	100 g	-813, 790, 115
na	Tape switches	1.5	Runway

* Referenced from the center of the right wheel hub.

c. High-Speed Photography. The crash tests were photographed using nine high-speed cameras with an operating speed of 500 frames/s. All high-speed cameras used Kodak 2253 daylight film. The high-speed film was analyzed for impact speed and acceleration data. In addition to the high-speed cameras, one real-time camera loaded with Kodak 7239 daylight film and two 35-mm still cameras were used to document the test. Table 4 summarizes the cameras used and their respective placements.

Table 4. Summary of camera placement.

Camera	Type	Film Speed Frames/s	Lens (mm)	Location
1	LOCAM II	500	100	Right 90° to impact
2	PHOTEC	500	50	Right 90° to impact
3	LOCAM II	500	75	Right side 45° to impact
4	LOCAM II	500	30	Right side 45° to impact
5	LOCAM II	500	150	180° to impact downrange
6	LOCAM II	500	50	Left side 45° to impact
7	LOCAM II	500	75	Left side 90° to impact
8	LOCAM II	500	10	Overhead
9	LOCAM II	500	5.7	On-board
10	BOLEX	24	ZOOM	Documentary
11	CANNON AE-1	still	ZOOM	Documentary
12	CANNON AE-1	still	ZOOM	Documentary

DATA ANALYSIS

Data were collected via the FOIL analog tape recorder system, including speed-trap data, the FOIL ODAS III on-board data acquisition system, and high-speed film.

a. Speed Trap. As the vehicles passed over the speed trap, electronic pulses from the five contact switches were recorded to analog tape. The tape was played back through a Data Translation ADC inside a desktop computer. The time intervals between the first pulse and each of the subsequent four pulses were then obtained using the analysis software provided with the ADC. The displacement vs. time data were then entered into a computer spreadsheet and a linear regression was performed to determine the best-line fit of the data points. The impact velocity was then determined from the slope of the best-line fit of the displacement vs. time curve.

b. Transducer Data Package. After the test, data were digitally converted and stored. The data from the tape recorder system and the ODAS III system were converted to the ASCII format, zero bias was removed, and data were digitally filtered using a digital Butterworth low-pass filter. The data from the crash tests were digitally filtered with a cut-off frequency of 300 Hz (Society of Automotive Engineers (SAE) Class 180). The data were transferred to a spreadsheet for analysis.

The cg acceleration data were integrated twice to produce velocity and displacement traces. Using techniques described in NCHRP Report 350, the occupant impact velocity (OIV) and ridedown acceleration criteria were determined. The rate transducer signals were integrated to produce angle vs. time traces to observe post-collision vehicle trajectory and stability. Acceleration vs. time traces were plotted for all FMVSS 208 accelerometers.

c. High-Speed Photography. Each crash event was recorded on 16-mm film by nine high-speed cameras. The camera perpendicular to the vehicle trajectory with a 50-mm lens and the overhead camera with a 10-mm lens were the only cameras used for high-speed film analysis. Analysis of each crash event was performed using an NAC Film Motion Analyzer model 160-F in conjunction with a desktop personal computer. The motion analyzer digitized the 16-mm film, reducing the image to Cartesian coordinates. The Cartesian coordinate data were then imported into a computer spreadsheet for analysis. Using the Cartesian coordinate data, a displacement vs. time history of each test was obtained. A linear regression was performed on the first 20 data points of the displacement vs. time traces to determine the impact velocities of the vehicles. The film was used to verify data obtained from the speed trap and rate transducer and could be used in the event of transducer malfunction. The film was used to observe roll, pitch and yaw angular displacements. The speed trap and accelerometer data were used as the primary sources of data.

RESULTS

In each crash test, the portable sign trailers were struck at the intended location by the Ford Festiva. Each vehicle was accelerated to within 1 km/h of the intended target test speed. Table 5 summarizes the results from each crash test.

Table 5. Summary of portable sign trailer testing.

Test number	98F008	98F009
Vehicle inertial weight	819 kg	818 kg
Speed: Speed trap (primary)	100.4 km/h	99.1 km/h
16-mm film	99.1 km/h	98.0 km/h
Peak longitudinal acceleration Class 180 data	16.8 g's	50.6 g's
Longitudinal OIV (limit 5 m/s)	3.3 m/s	3.5 m/s
10 ms ridedown (limit 20 g's)	0.9 g's	1.2 g's
Vehicle crush	159 mm	249 mm
Occupant compartment intrusion	None	None
Windshield damage	Cracked, no loss of visibility	Cracked, no loss of visibility

Test 98F008. The Ford Festiva was accelerated to 100.4 km/h prior to striking the portable sign trailer. The Ford Festiva centerline struck the sign trailer at one wheel as intended. The wheel of the sign trailer began to tuck under the vehicle and the axle began to buckle directly behind the wheel at 0.006 s. Movement of the sign trailer frame was observed at 0.010 s. The sign trailer pivoted about the end of the trailer tongue at the hitch. The struck wheel had folded over flat but remained attached to the axle by 0.054 s. The folded wheel assembly and buckled axle initiated the sign panel motion toward the windshield. The sign panel made contact with the windshield at 0.100 s. No contact between the sign post or panel and the hood was observed. As the vehicle continued to push on the end of the axle and sign panel, the sign trailer continued to rotate clockwise. The sign trailer was also being lifted by the vehicle's front end. The vehicle remained in contact with the sign trailer until approximately 0.250 s. The vehicle continued to rotate the sign trailer; the sign trailer was forced to the right of the vehicle, away from the vehicle path. The sign trailer rotated about 270° while airborne and the tongue of the sign trailer caught briefly inside the right wheel well and the latch of the trailer hitch snagged the rim of the wheel well, becoming wedged in the sheet metal fender. The sign trailer fell to the ground and upon impact the struck wheel broke from the trailer axle and rolled downrange. The vehicle brakes were applied and the vehicle came to rest just prior to contact with the FOIL catch fence.

The peak longitudinal acceleration recorded was 16.8 g's (135 kN). The longitudinal vehicle change in velocity was 3.6 m/s. The rate transducer located at the vehicle cg recorded insignificant pitch, roll, and yaw angular rates. Table 6 summarizes the peak accelerations recorded by each accelerometer attached to the test vehicle.

Table 6. Summary of class 180 data and accelerometer locations, test 98F008.

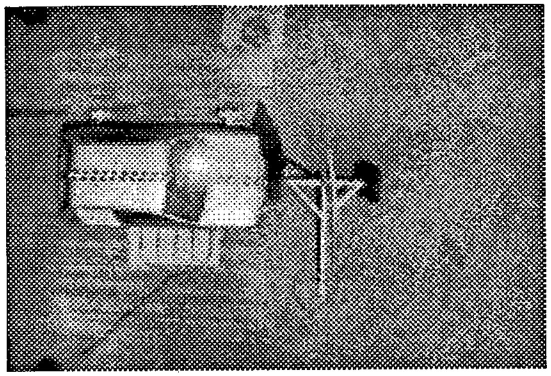
Location	**Peak Acceleration (g's)**	
	Max (+)	**Max (-)**
Top of engine	18.5	82.3
Bottom of engine	187.2	430.6
Left control arm	34.2	72.4
Right control arm	23.8	48.3
Instrument panel	15.3	45.3
Cg X-axis	17.8	16.8
Cg X-axis redundant	13.8	22.2
Cg Y-axis	8.6	12.5
Cg Z-axis	9.7	7.3

a. Occupant responses. The longitudinal OIV for the test was determined to be 3.3 m/s and occurred 0.233 s after initial contact. The longitudinal ridedown acceleration was 0.9 g's. There was no lateral occupant impact during the vehicle/sign trailer contact.

b. Vehicle damage. Damage to the Ford Festiva consisted of minor to significant cosmetic dents to the bumper and roof. The maximum crush of the bumper was 159 mm and the roof was dented approximately 20 mm. The windshield was cracked but there was no intrusion and no loss of visibility. No debris from the test vehicle was observed in the runout path of the vehicle. The vehicle trajectory did not change after contact with the sign. No yaw was observed in the test vehicle's path. The vehicle remained stable throughout the test.

c. Test device damage. Damage to the portable sign trailer was substantial. The axle and sign post buckled severely. The sign panel remained fastened to the sign post, and the post remained inside the trailer sleeve. The sign trailer landed 49 m downrange and to the right of the test vehicle's trajectory. The struck wheel hub broke at the spindle and the tire rolled 103 m downrange. The sign trailer could not be repaired and reused without significant structural repair.

Figure 5 includes photographs of the sign trailer and the test vehicle during the test. Figure 6 is a summary sheet of the test parameters and test results and depicts the post-test locations of the test elements. Figures 7 and 8 are photographs that document the sign trailer and test vehicle before and after the crash test. Figures 9 through 22 are data plots from the sensors affixed to the test vehicle. The data plots are of class 180 data.



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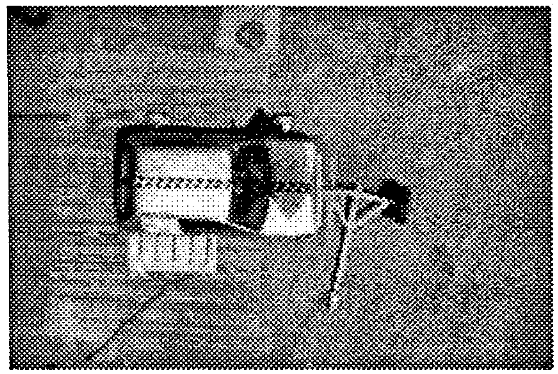

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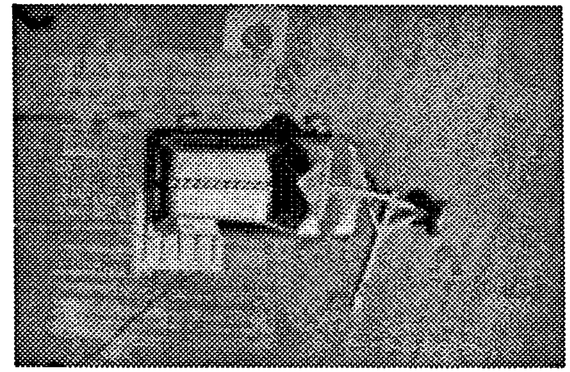

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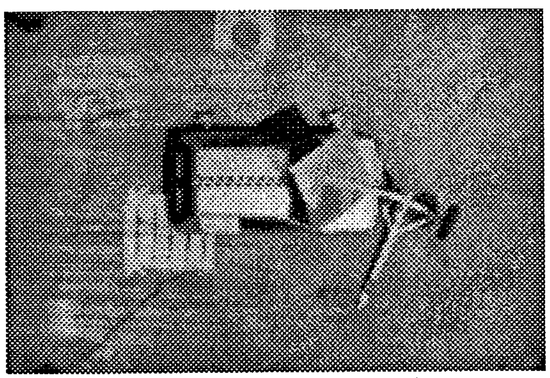

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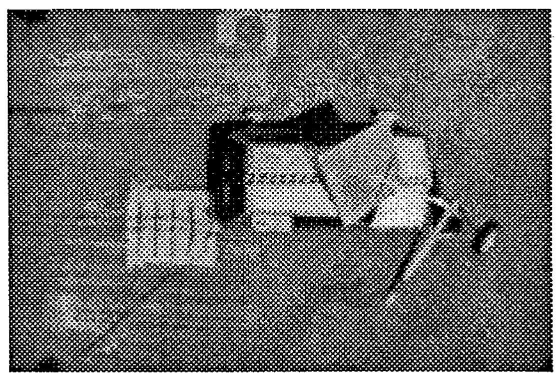
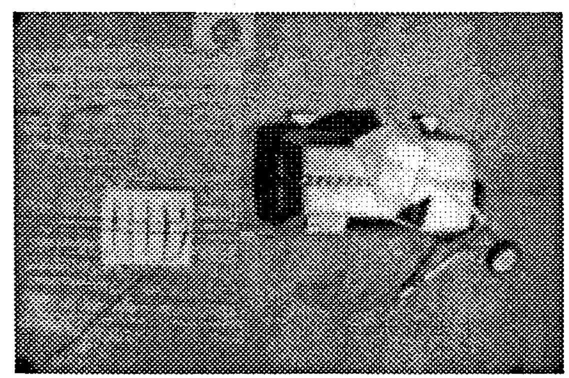
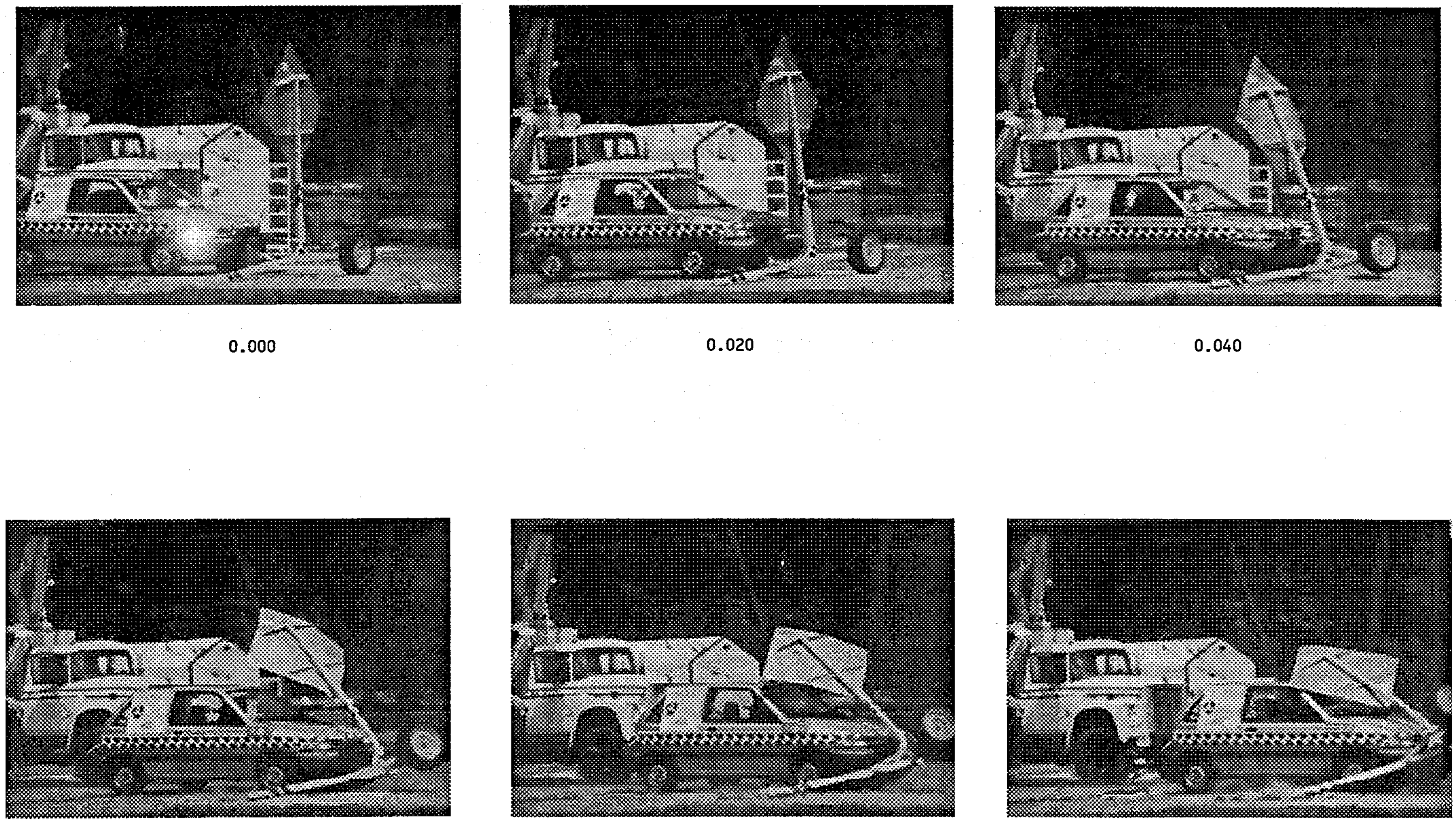


0.110



0.160

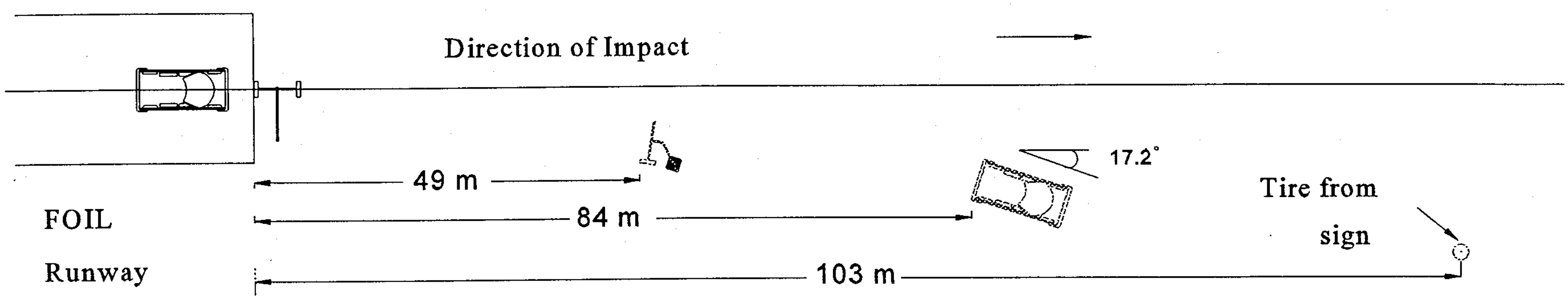
Figure 5. Test photographs during impact, test 98F008.



0.000 0.020 0.040

0.070 0.090 0.116

Figure 5. Test photographs during impact, test 98F008 (continued).



Test number............................98F008

Date...............................May 28, 1998

Test article....work-zone portable sign trailer
Support..........50 mm box tube post set inside a steel sleeve

Tires.......................P205/75 R14

Tire pressure...................220 kPa
Sign panel.......aluminum 1.7 m by 1.7 m

Foundation.........placed at end of FOIL runway

Vehicle.....................1990 Ford Festiva

Weight: Inertial.................819 kg
Gross....................888 kg
Dummy.....................68 kg

Impact speed.......................100.4 km/h

Impact location............at one tire, center

Impact angle........................0 degrees

Vehicle analysis:	Observed	Design/Limit
Longitudinal:		
Vehicle Delta V	3.6 m/s	3/5 m/s
Occupant Delta V at 0.6 m	3.3 m/s	9/12 m/s
Ridedown acceleration	0.9 g's	15/20 g's
Lateral:		
Occupant Delta V at 0.3 m	N/A	9/12 m/s
Ridedown acceleration	N/A	15/20 g's
Peak 50 ms acceleration:		
Longitudinal		5.3 g's
Lateral		N/A
Vehicle Damage:		
Traffic Accident Data (TAD)		12-FC-2
Vehicle Damage Index (VDI)		12TDCN1
Vehicle crush		159 mm

Figure 6. Summary of test 98F008.

Figure 7. Pretest photographs, test 98F008.

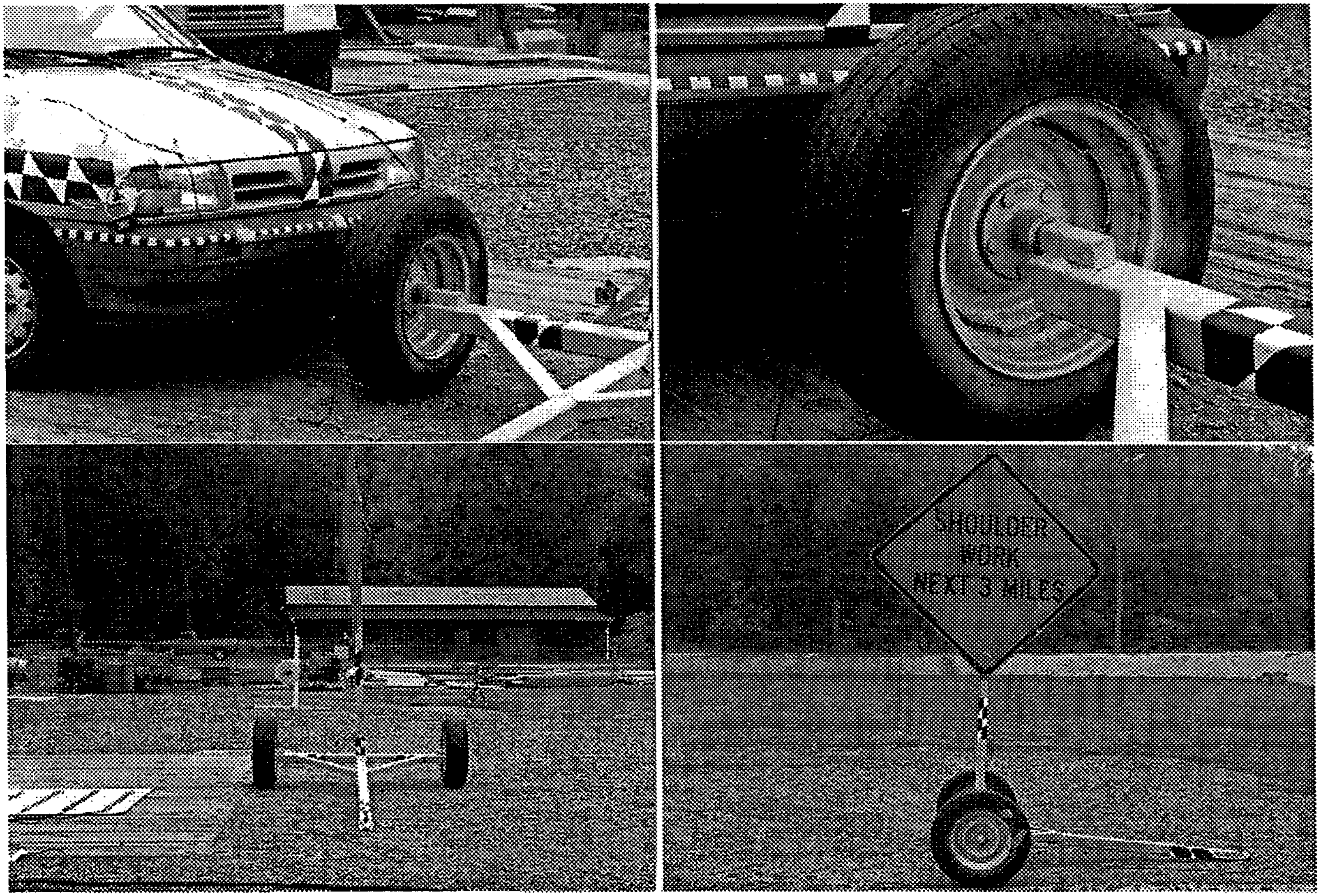


Figure 7. Pretest photographs, test 98F008 (continued).

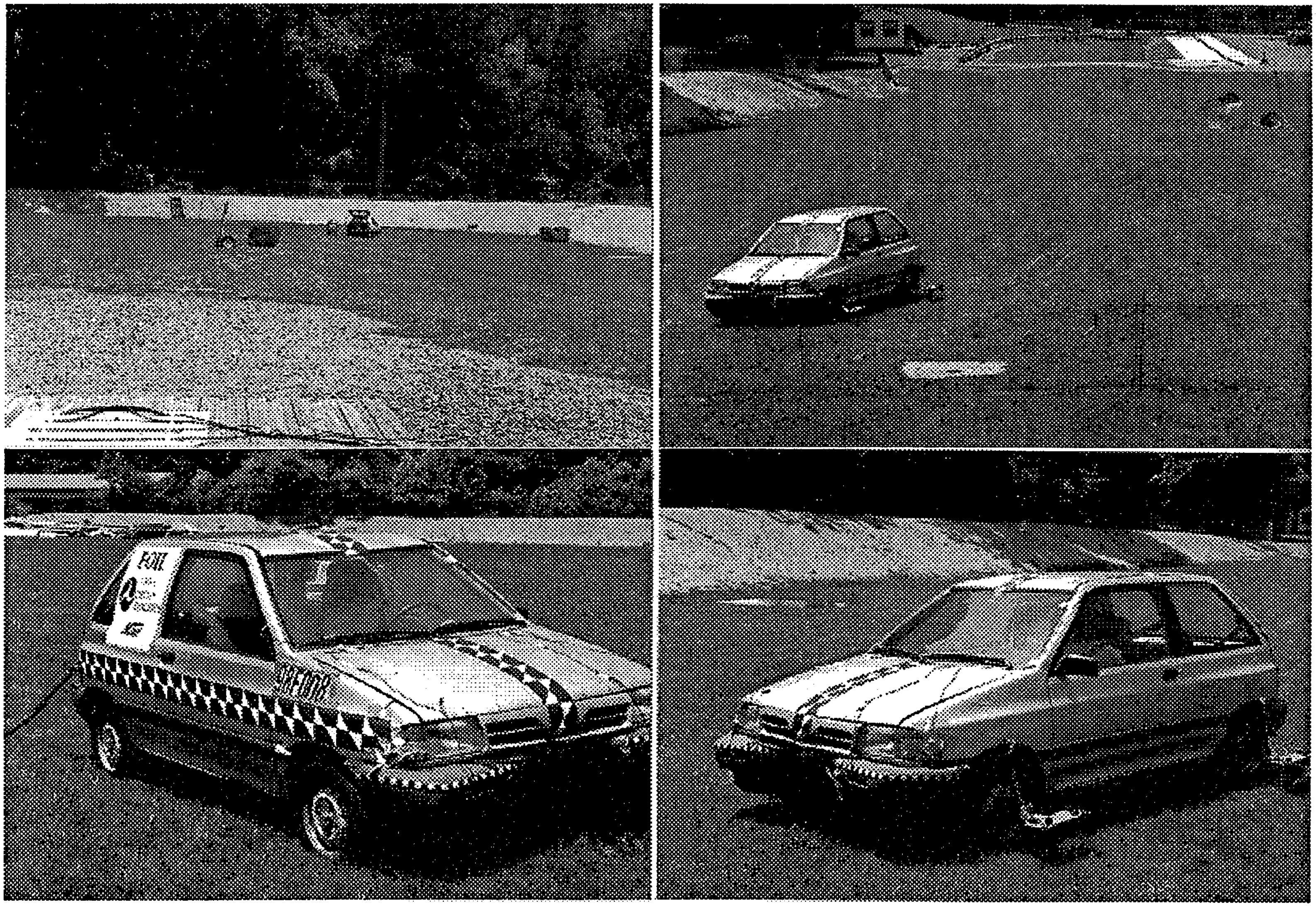


Figure 8. Post-test photographs, test 98F008.

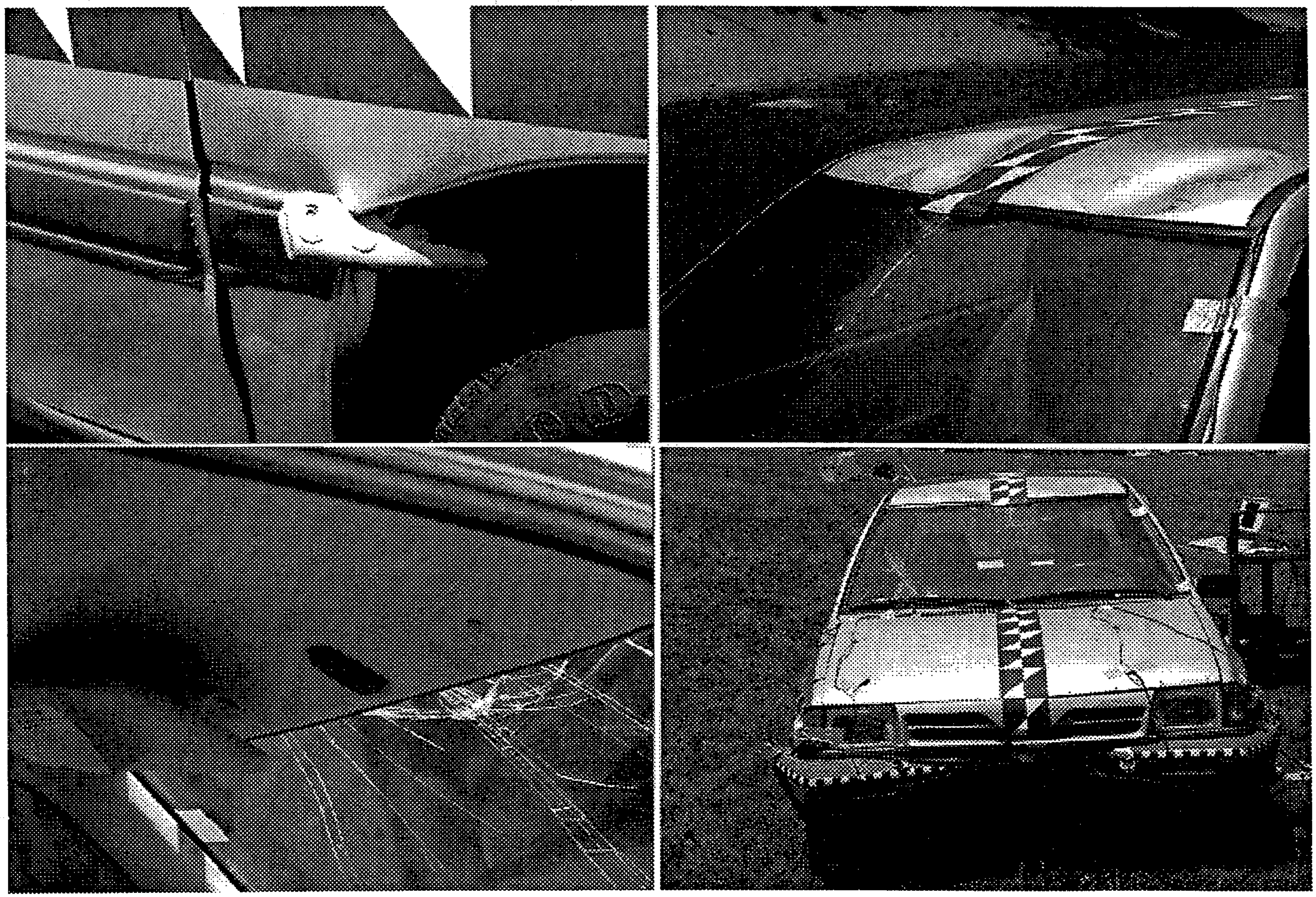


Figure 8. Post-test photographs, test 98F008 (continued).

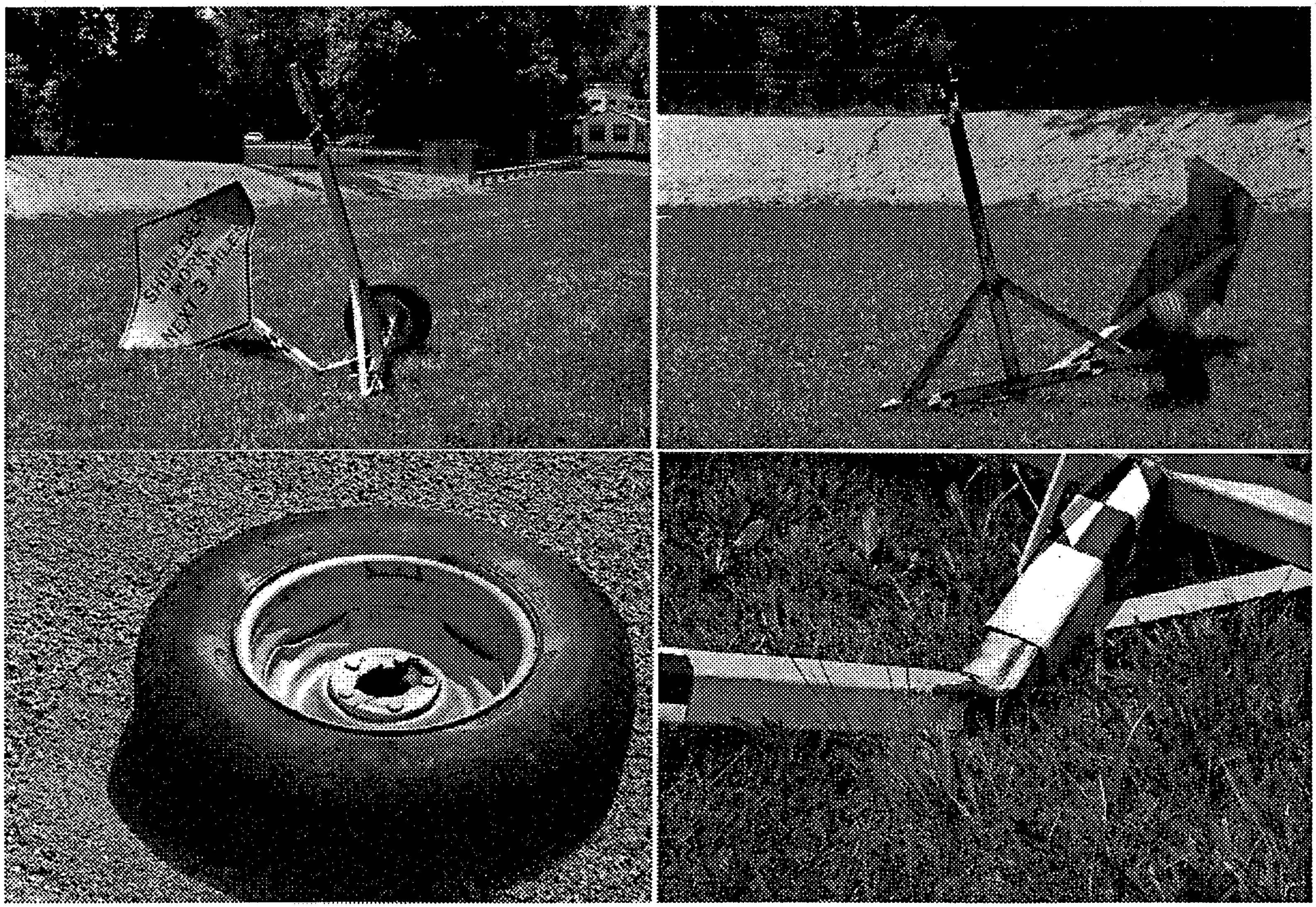


Figure 8. Post-test photographs, test 98F008 (continued).

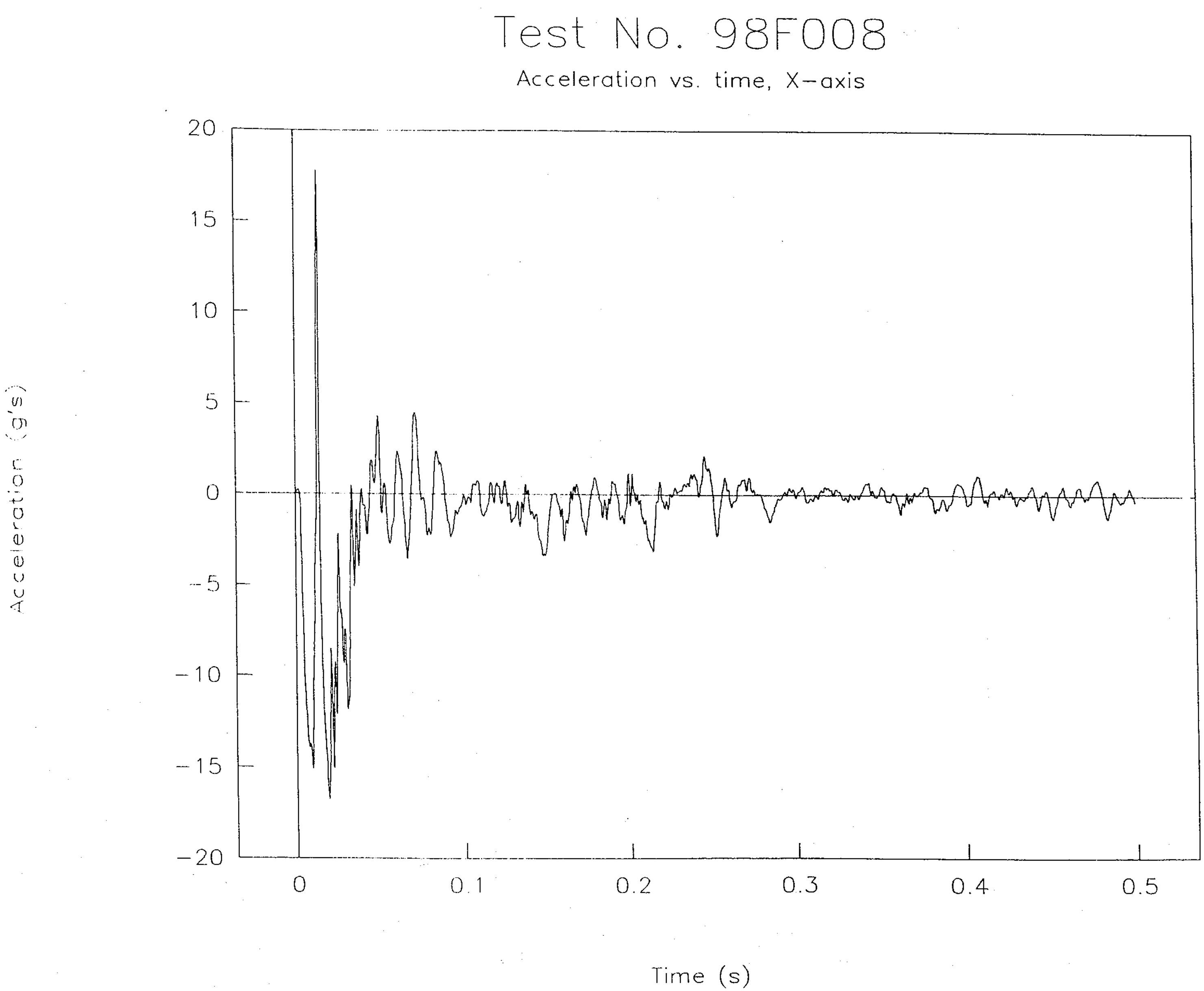


Figure 9. Acceleration vs. time, X-axis, test 98F008.

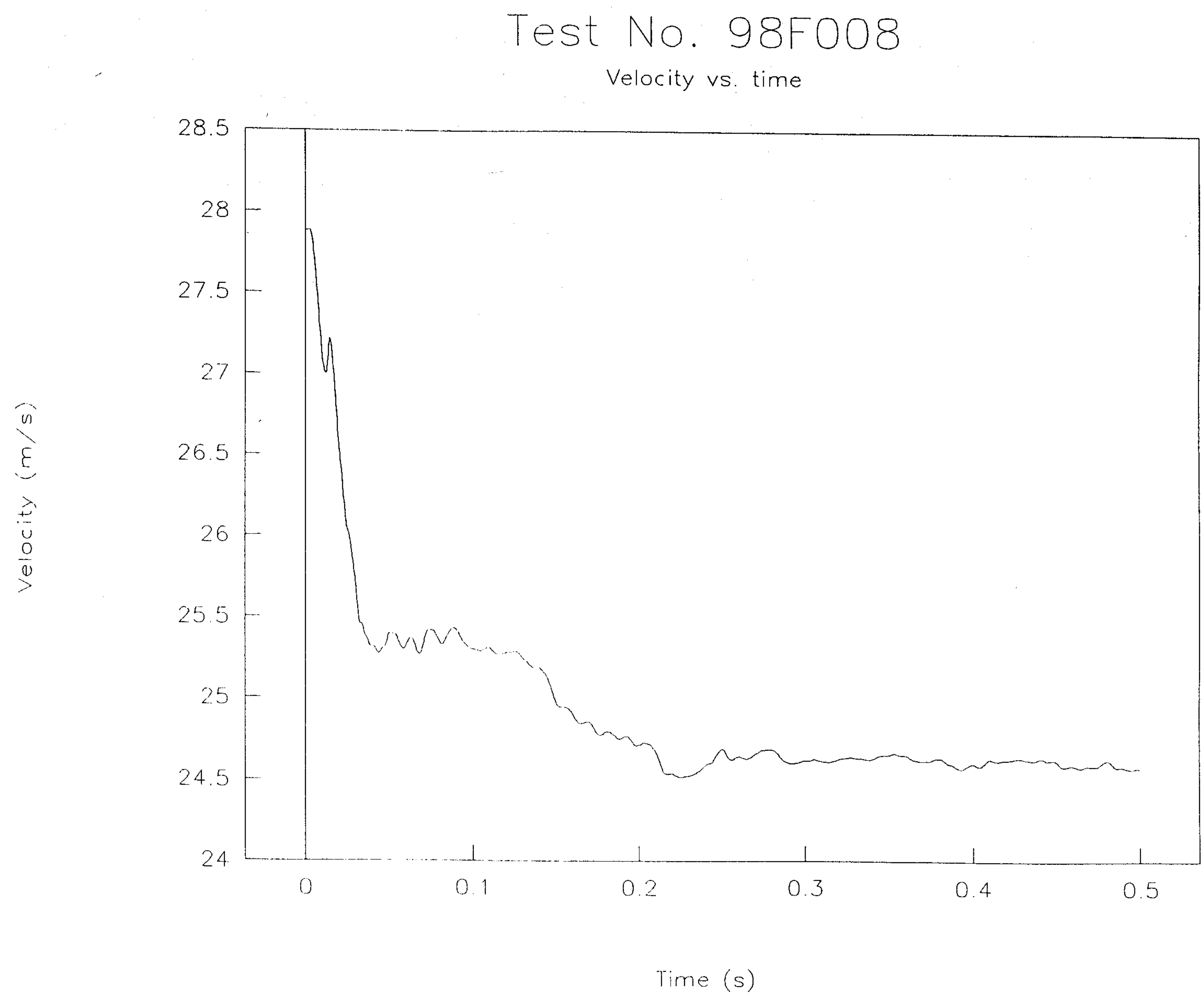


Figure 10. Velocity vs. time, test 98F008.

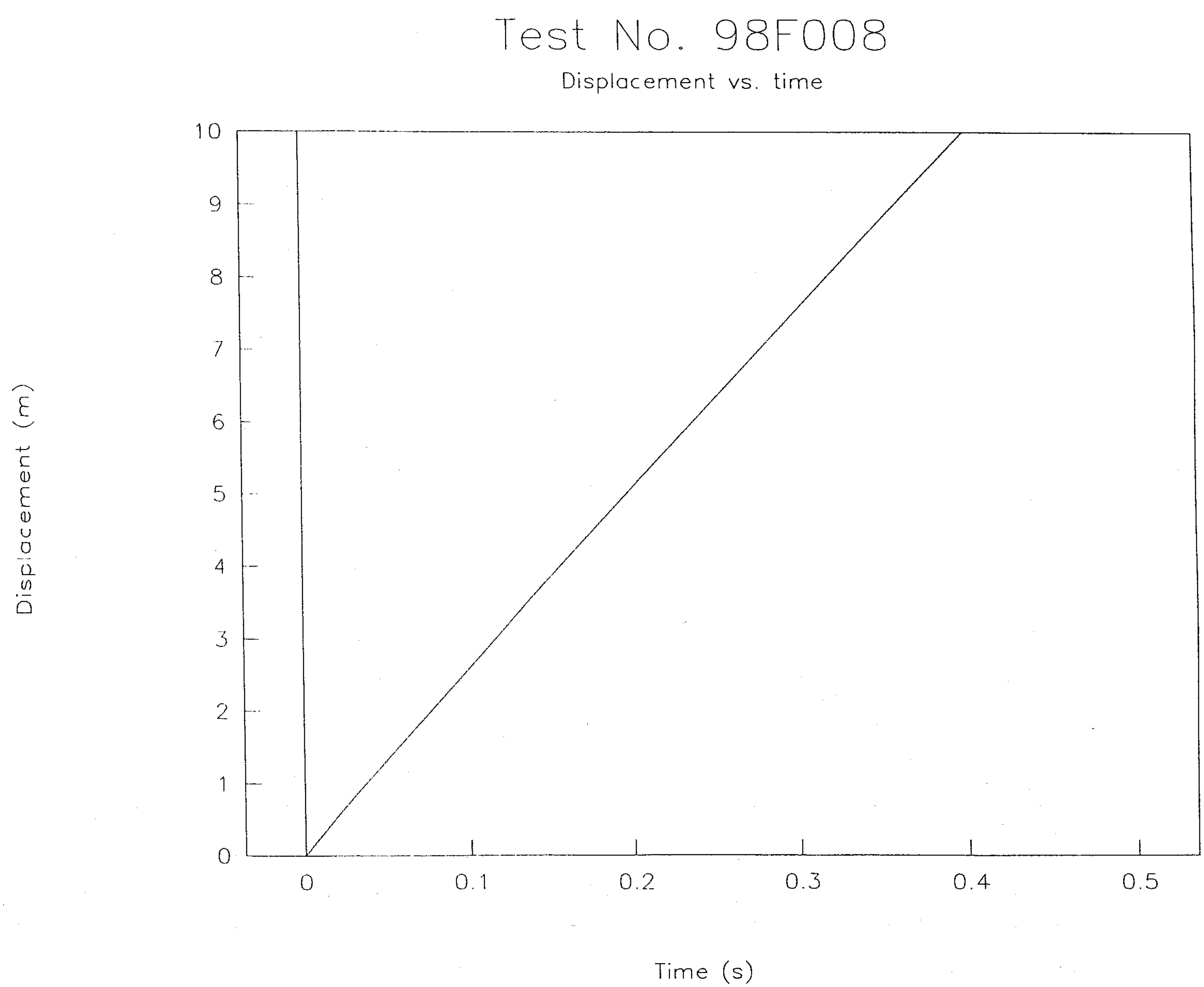


Figure 11. Displacement vs. time, test 98F008.

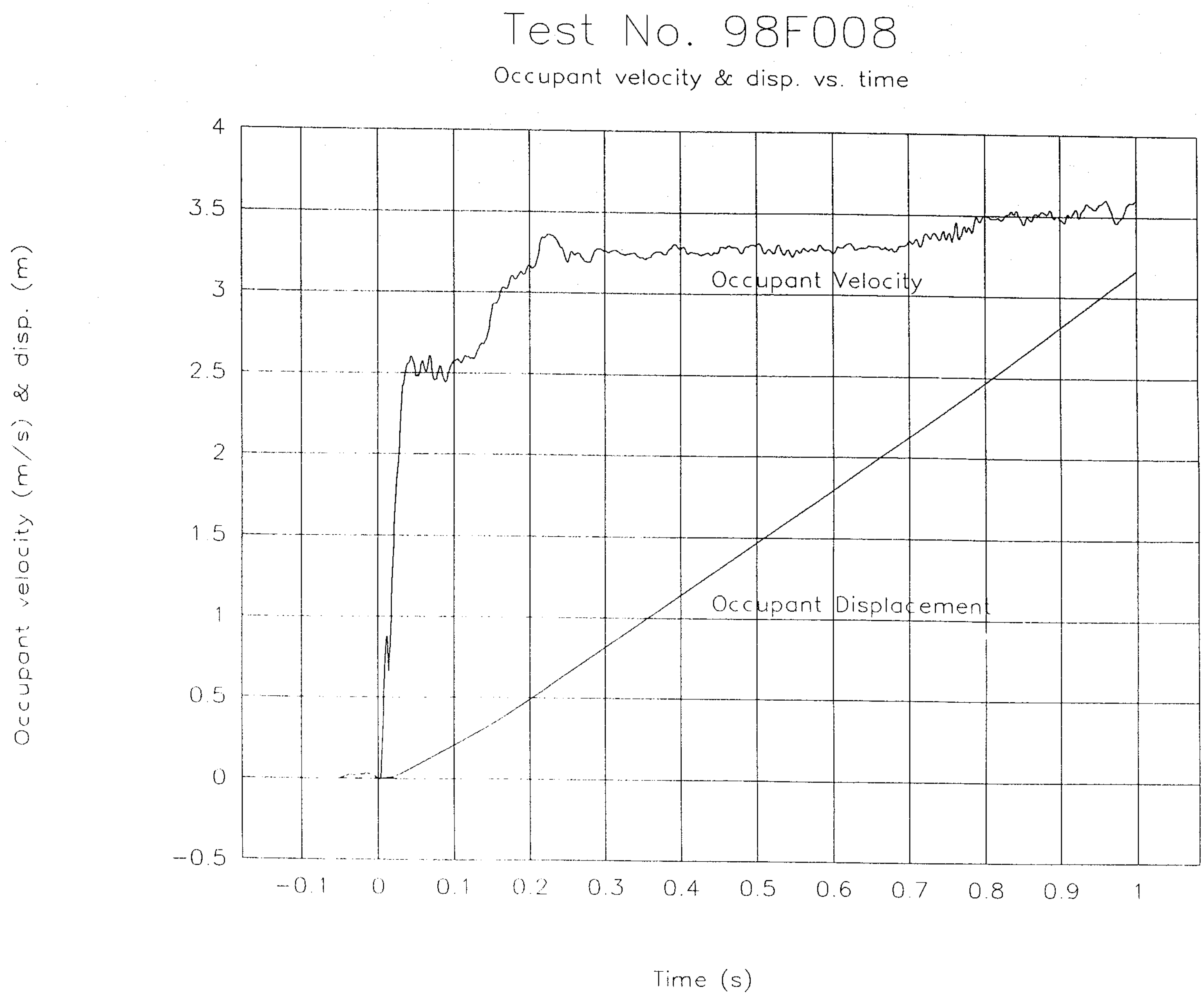


Figure 12. Occupant velocity and displacement vs. time, test 98F008.

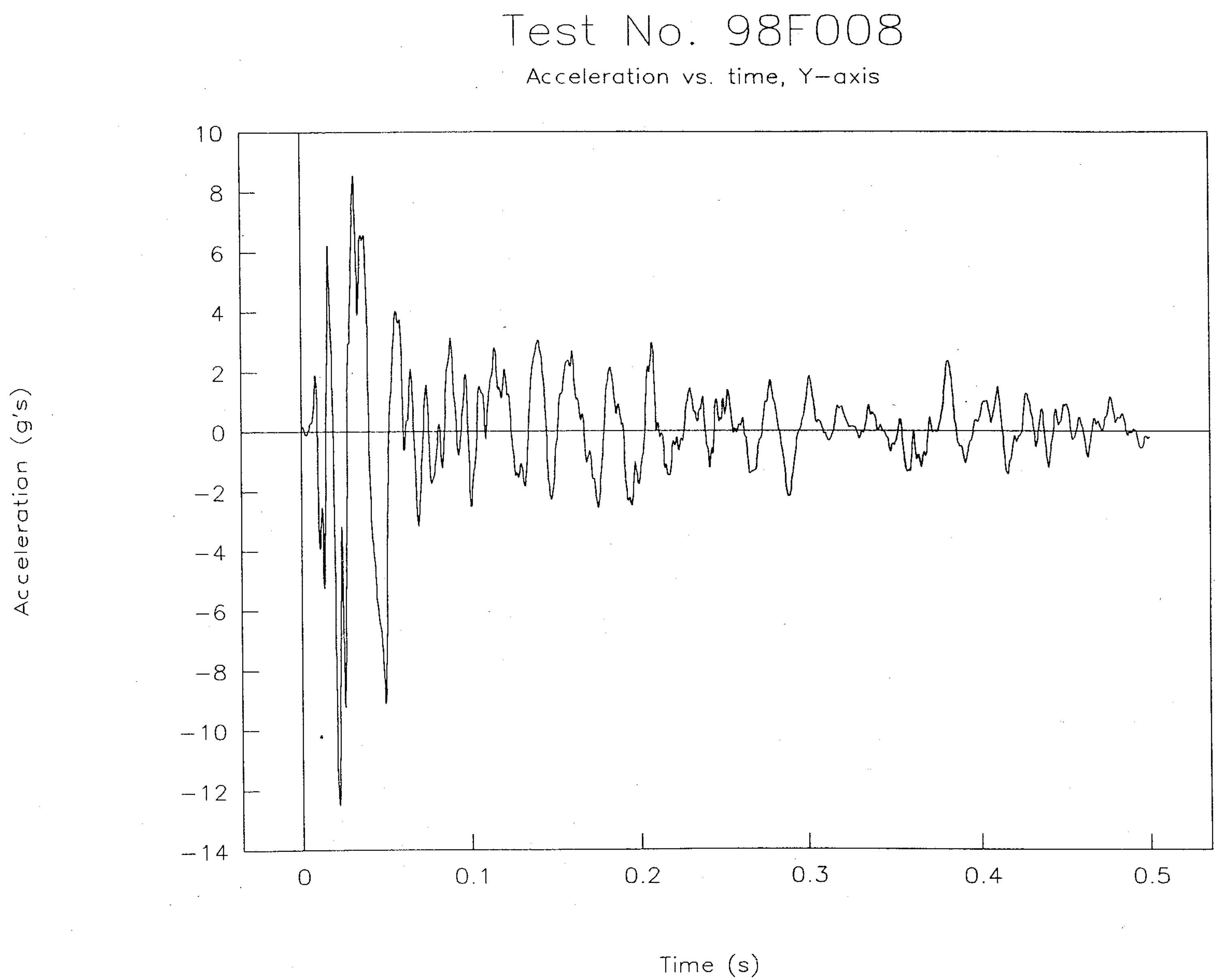


Figure 13. Acceleration vs. time, Y-axis, test 98F008.

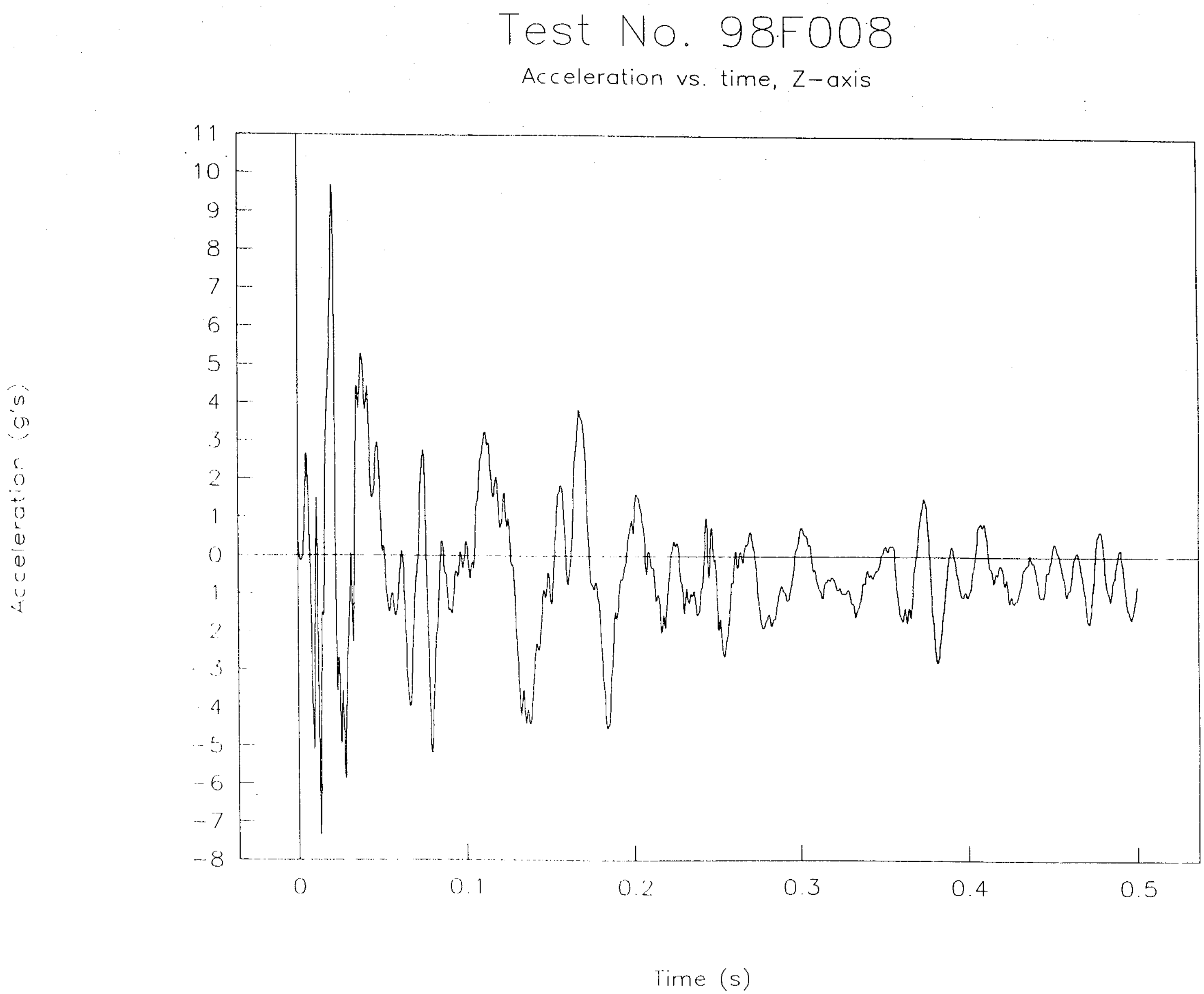


Figure 14. Acceleration vs. time, Z-axis, test 98F008.

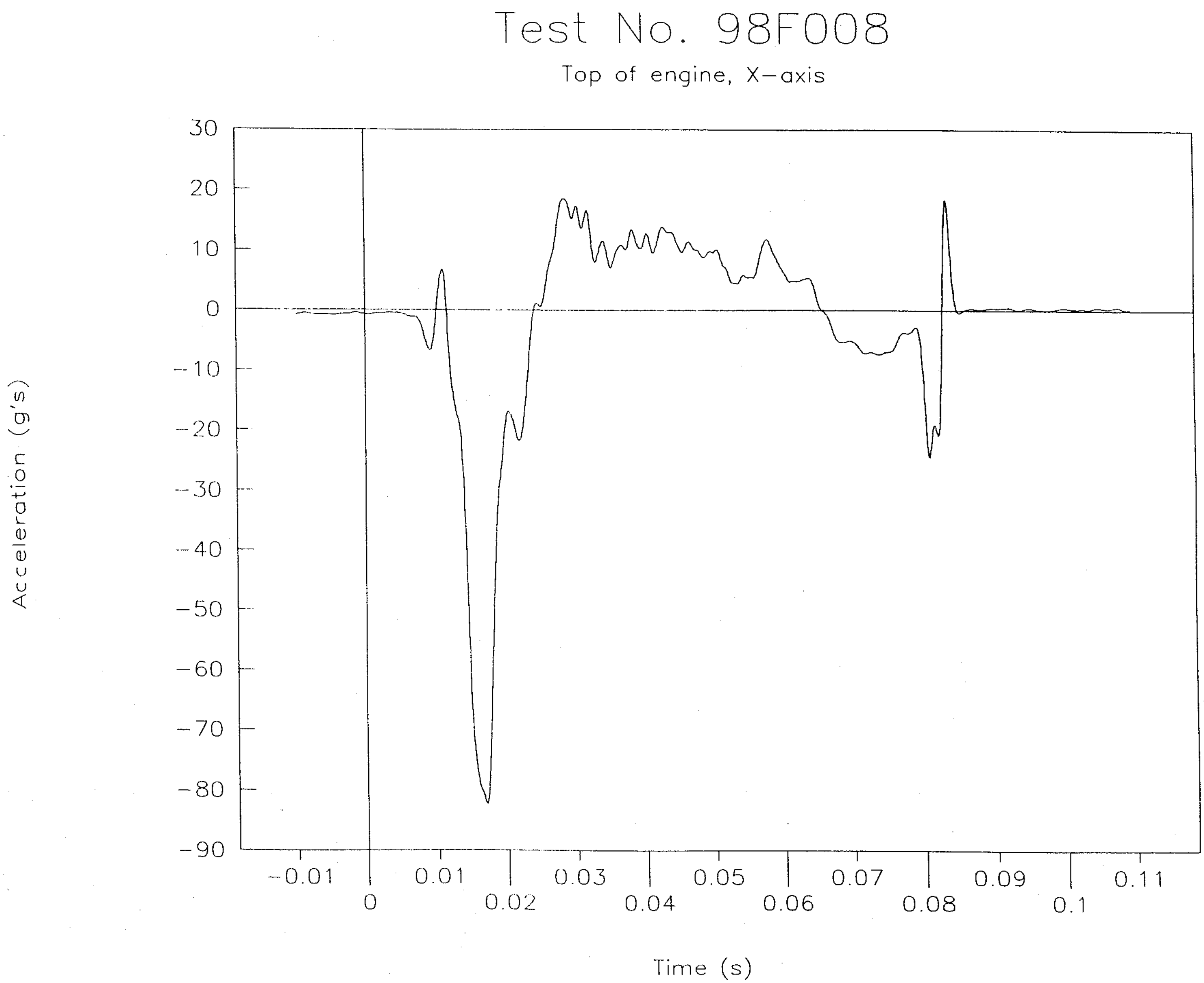


Figure 15. Acceleration vs. time, top of engine, X-axis, test 98F008.

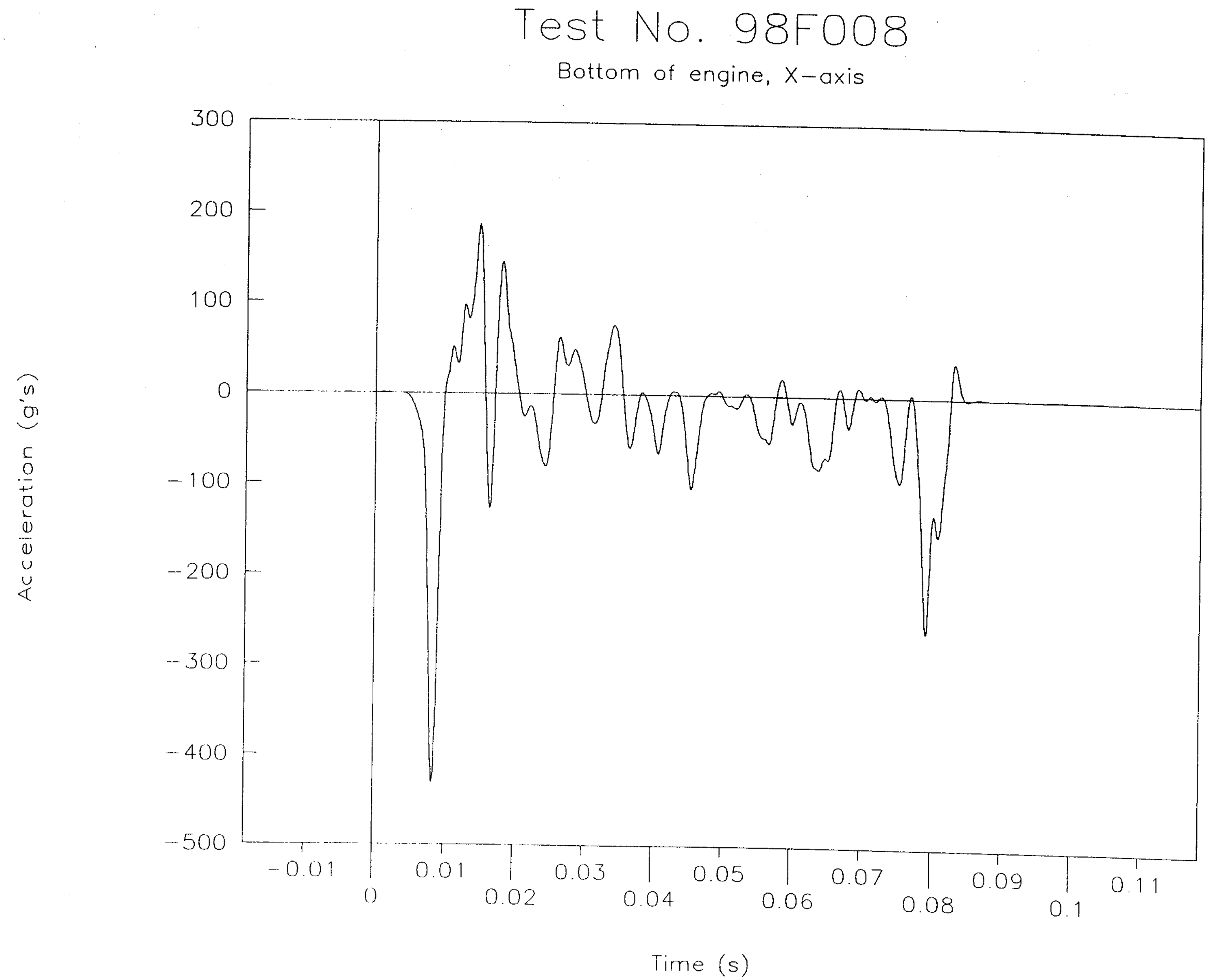


Figure 16. Acceleration vs. time, bottom of engine, X-axis, test 98F008.

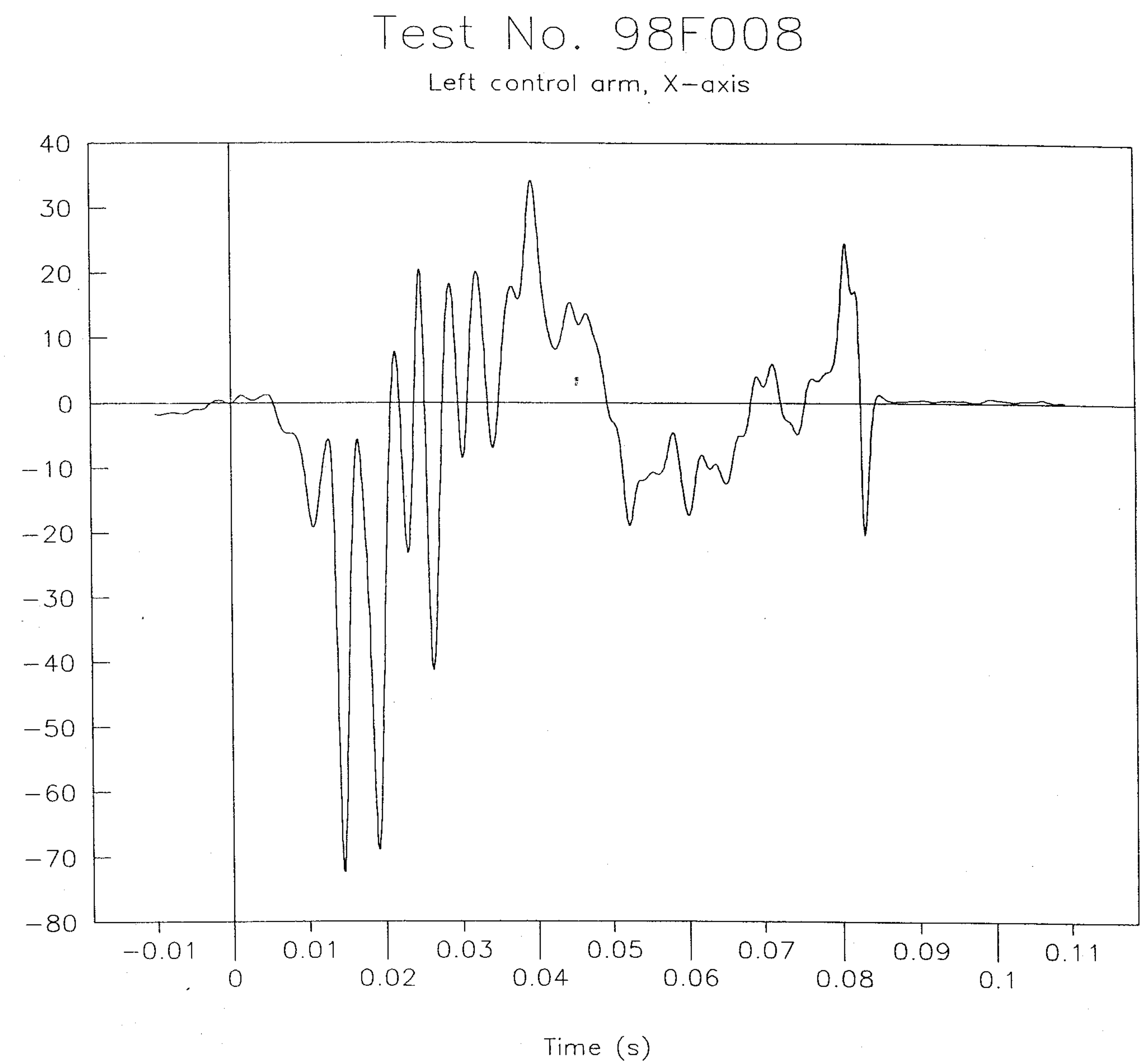


Figure 17. Acceleration vs. time, left control arm, X-axis, test 98F008.

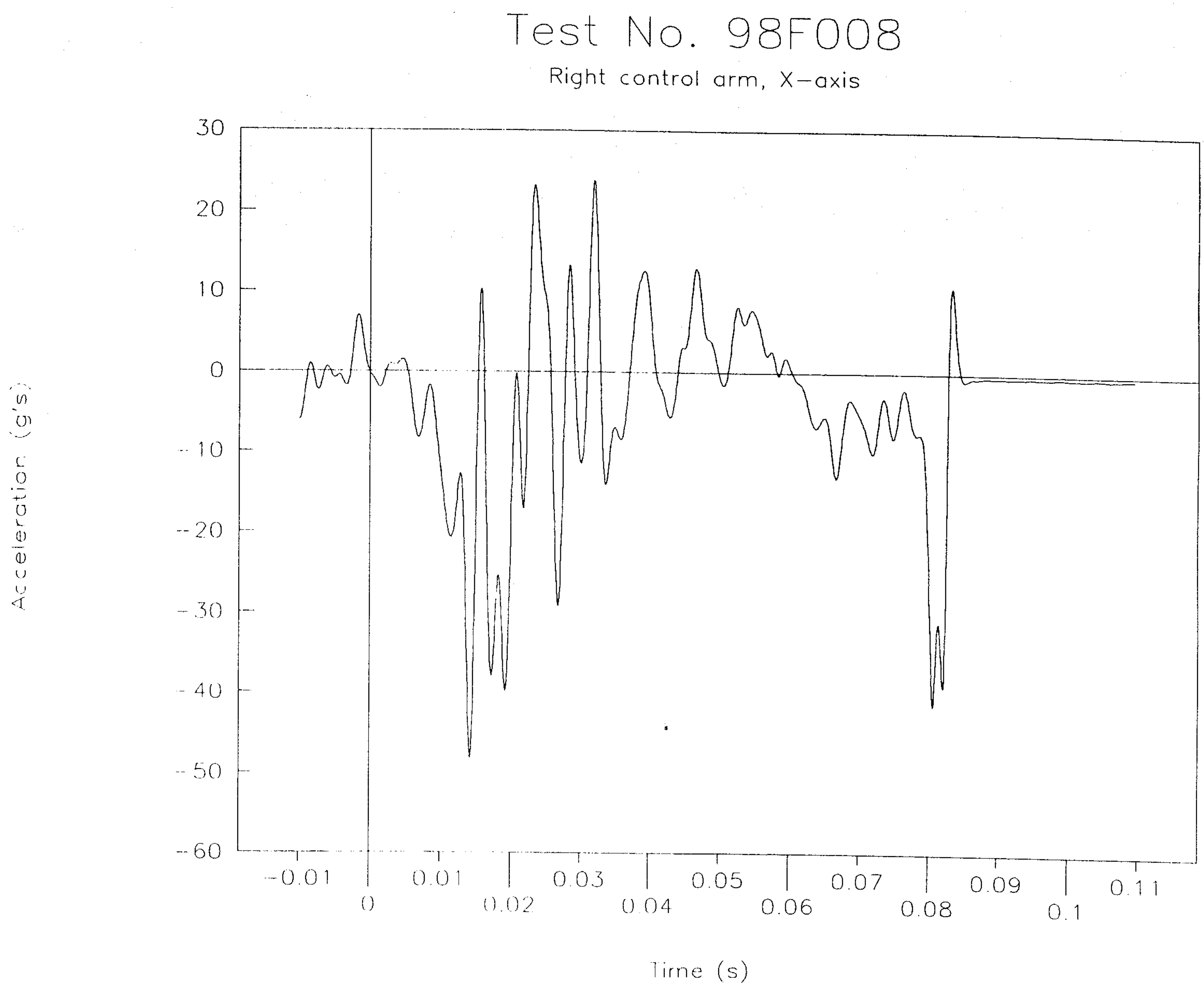


Figure 18. Acceleration vs. time, right control arm, X-axis, test 98F008.

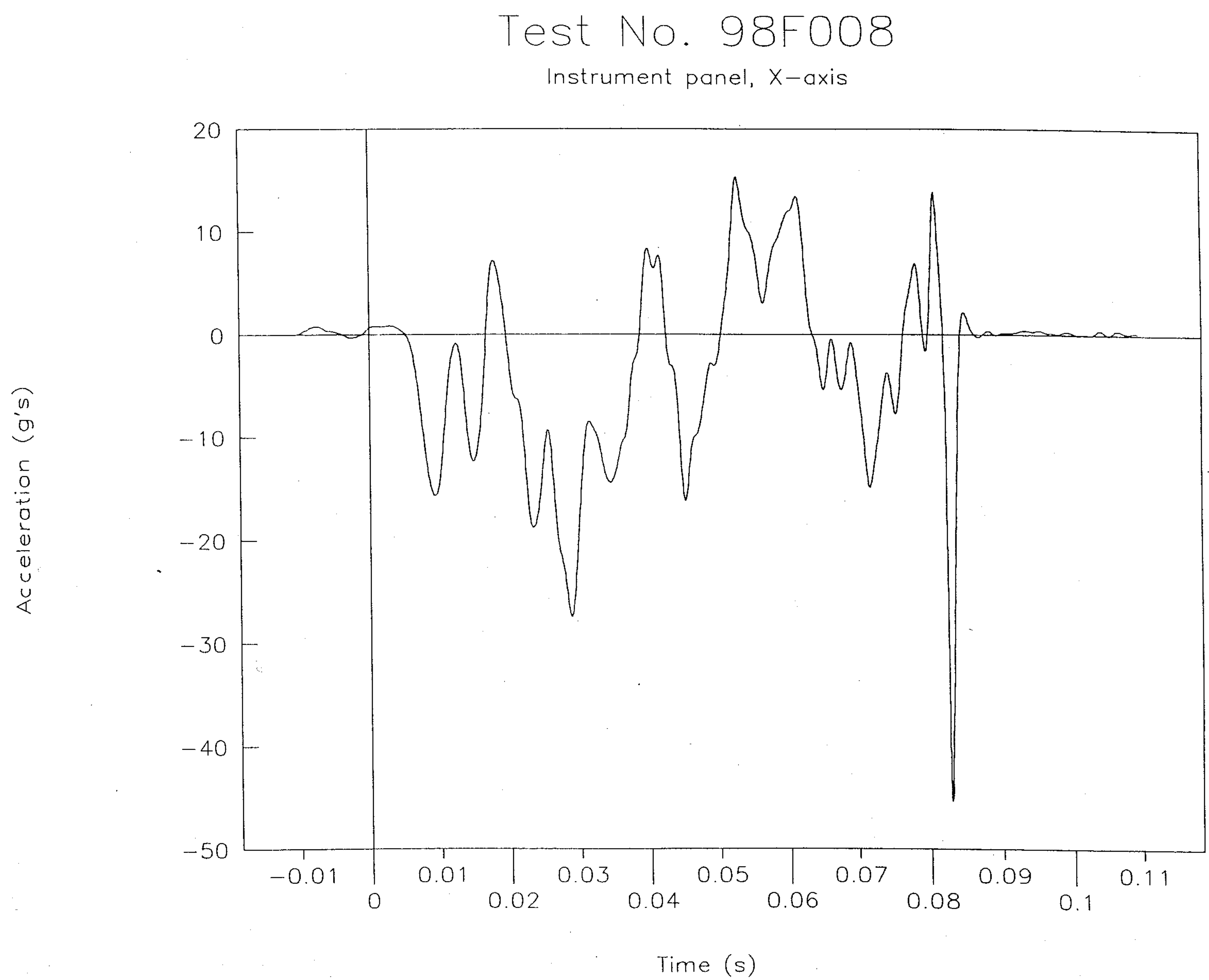


Figure 19. Acceleration vs. time, instrument panel, X-axis, test 98F008.

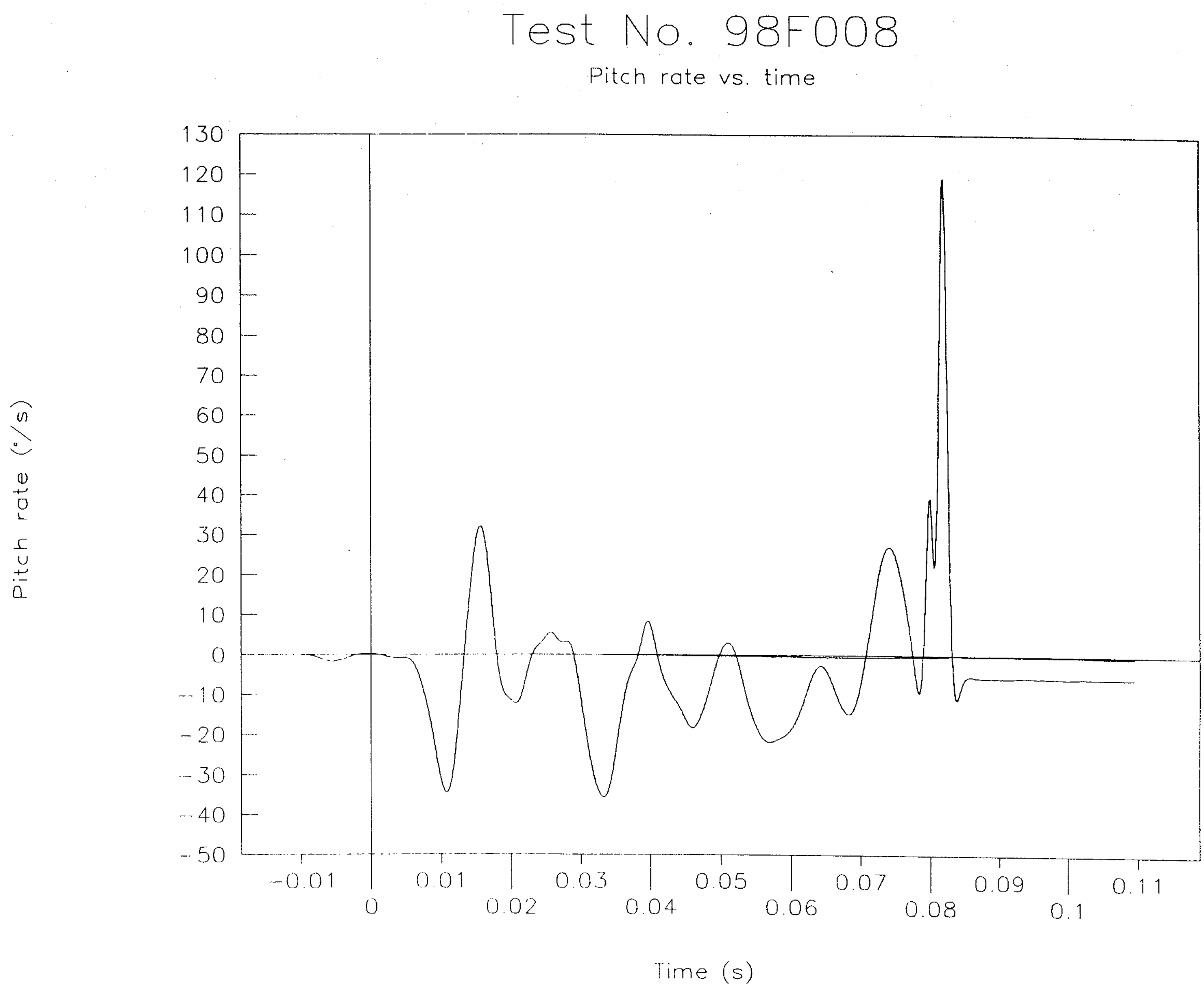


Figure 20. Pitch rate vs. time, test 98F008.

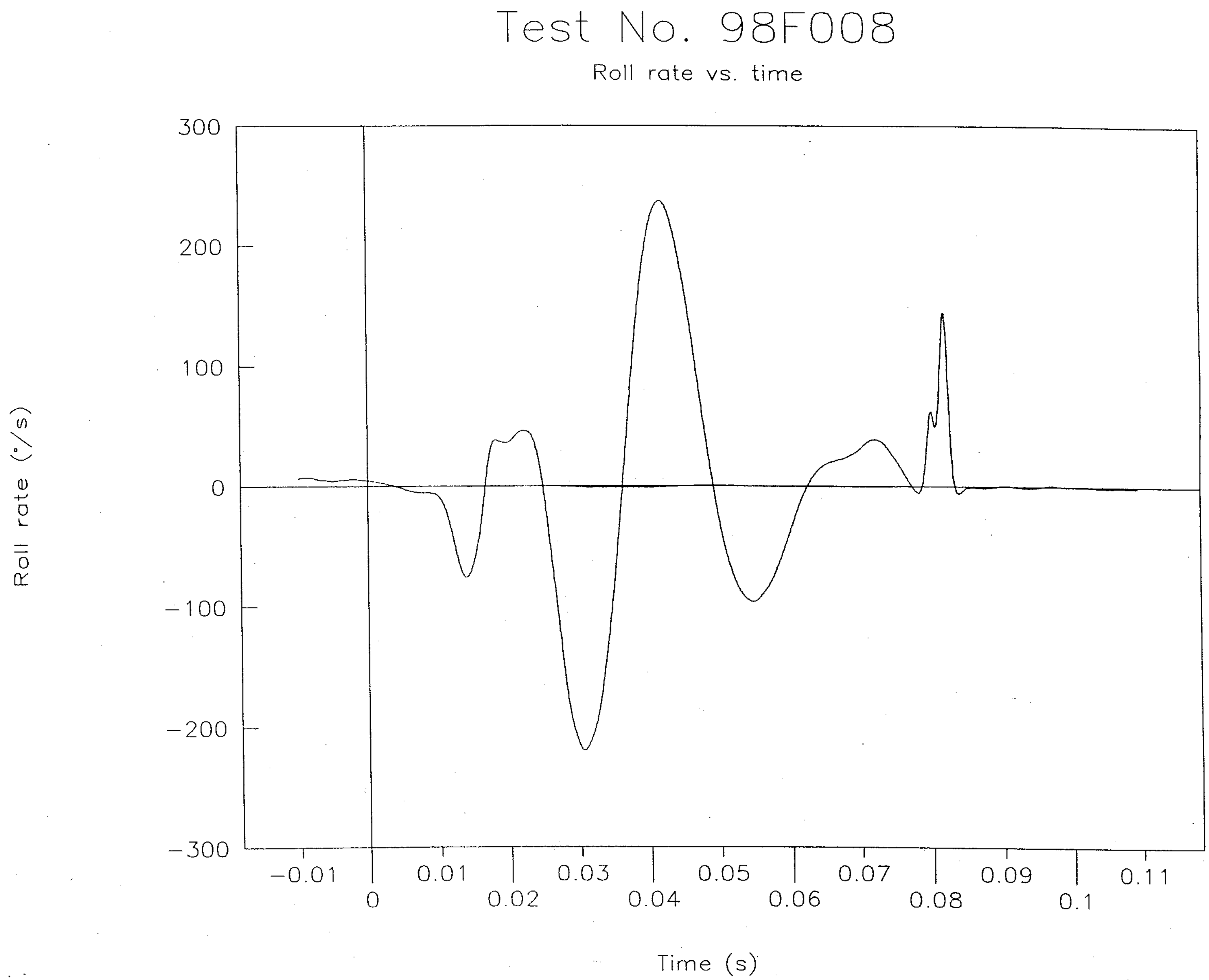


Figure 21. Roll rate vs. time, test 98F008.

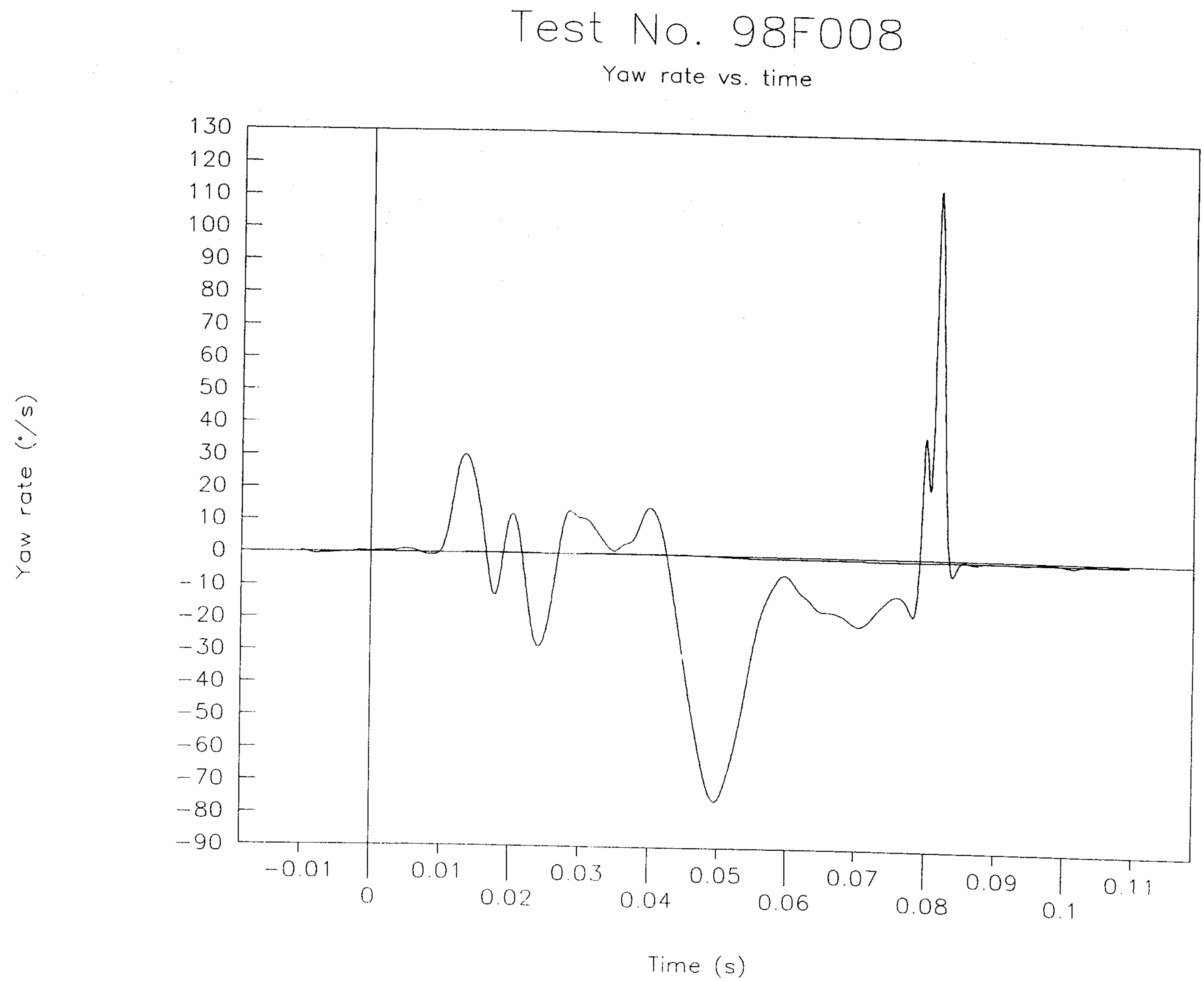


Figure 22. Yaw rate vs. time, test 98F008.

Test 98F009. The Ford Festiva was accelerated to 99.1 km/h prior to striking the portable sign trailer. The Ford Festiva centerline struck the sign trailer on the sign post between the trailer's two tires. The sign trailer began to move on contact and the bumper, grill, and hood had crushed significantly by 0.026 s. The vehicle bumper contacted the sign trailer 230 mm above the trailer's axle, but on the sign post sleeve (not directly on the sign post). The contact and the inertia of the tall sign post caused the sign panel and post to rotate down on top of the vehicle, striking the windshield at 0.110 s. The sign trailer's tongue and hitch pushed through the soil slightly before being rotated upward as the sign tipped toward the vehicle. The entire trailer was lifted up and rode on the hood of the vehicle before being launched upward and away from the vehicle. The maximum height of the sign trailer was approximately 2.3 m. The vehicle continued along its original line of trajectory. The sign trailer landed 75 m downrange from its original position and to the left of the vehicle's trajectory. The sign trailer remained intact, although with significant structural damage.

The peak longitudinal acceleration recorded was 50.6 g's (406 kN). The longitudinal vehicle change in velocity was 4.4 m/s. The rate transducer located at the vehicle cg recorded insignificant pitch, roll, and yaw angular rates. Table 7 summarizes the peak accelerations recorded by each accelerometer attached to the test vehicle.

Table 7. Summary of class 180 data and accelerometer locations, test 98F009.

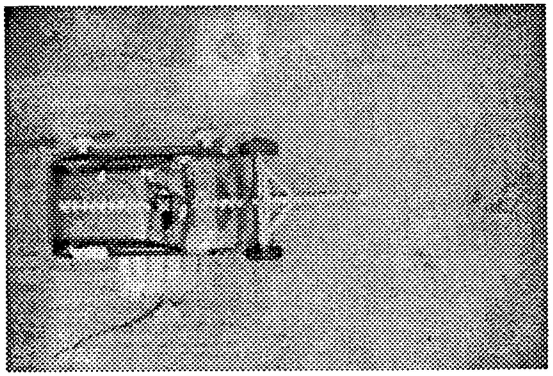
Location	**Peak Acceleration (g's)**	
	Max (+)	**Max (-)**
Top of engine	10.0	39.9
Bottom of engine	176.5	502.1
Left control arm	48.6	81.1
Right control arm	57.9	100.9
Instrument panel	20.0	36.5
Cg X-axis	7.8	15.4
Cg X-axis redundant	5.4	52.7
Cg Y-axis	132.8	145.1
Cg Z-axis	13.3	9.7

a. Occupant responses. The longitudinal OIV for the test was determined to be 3.5 m/s and occurred 0.196 s after initial contact. The longitudinal ridedown acceleration was 1.2 g's. There was no lateral occupant impact during the vehicle/sign trailer contact.

b. Vehicle damage. Damage to the Ford Festiva consisted of minor to significant cosmetic dents and crush of the bumper, hood, and roof. The maximum crush of the bumper was 249 mm and the roof was dented approximately 50 mm. The windshield was cracked but there was no intrusion and no loss of visibility. No debris from the test vehicle was observed in the runout path of the vehicle. The vehicle trajectory did not change after contact with the sign. No yaw was observed in test vehicle's path. The vehicle remained stable throughout the test.

c. Test device damage. Damage to the portable sign trailer was substantial. The axle and sign post did not buckle, however, the base of the sign sleeve tore from the axle. Both axle/spindle connections were bent inward, causing both wheels to have severe "toe-in." The sign panel remained fastened to the sign post and the post remained inside the trailer sleeve. The sign trailer landed 75 m downrange and to the left of the test vehicle's trajectory. The sign trailer could not be repaired and reused without significant structural repair.

Figure 23 includes photographs of the sign trailer and the test vehicle during the test. Figure 24 is a summary sheet of the test parameters and test results and depicts the post-test locations of the test elements. Figures 25 and 26 are photographs that document the sign trailer and test vehicle before and after the crash test. Figures 27 through 40 are data plots from the sensors affixed to the test vehicle. The data plots are of class 180 data.



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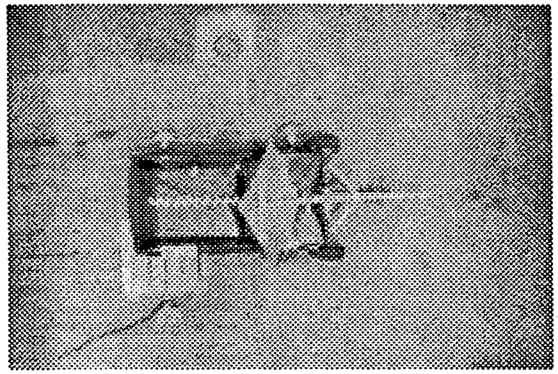
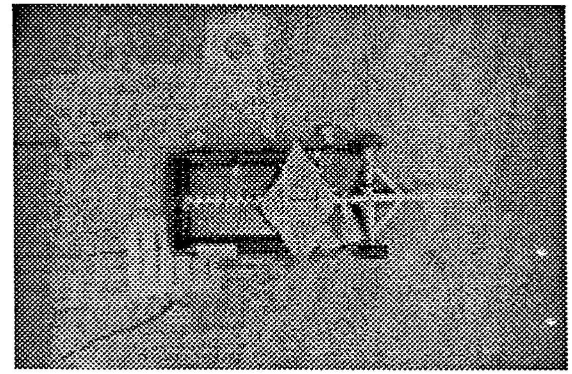


0.060



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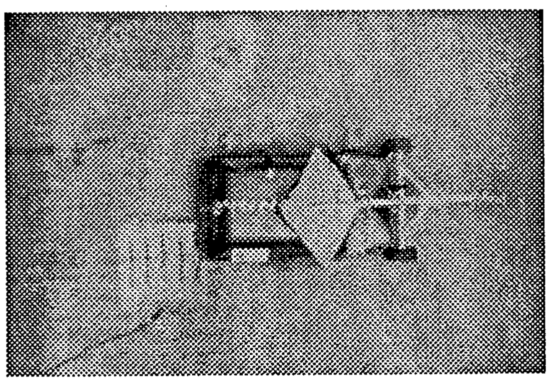
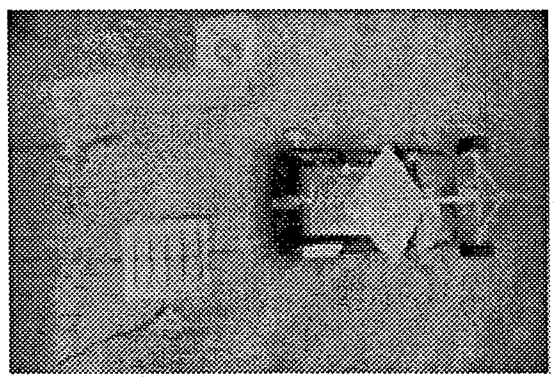
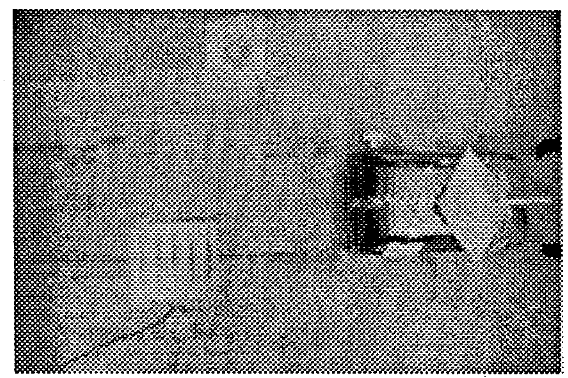


0.110



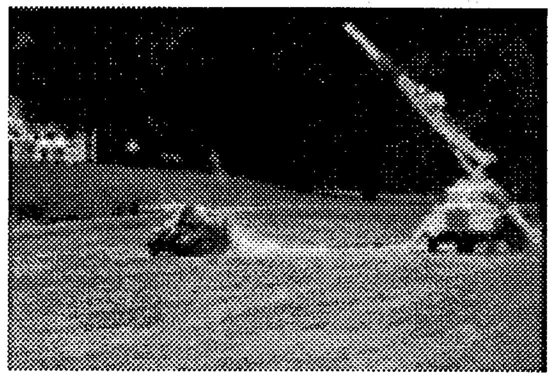
0.160



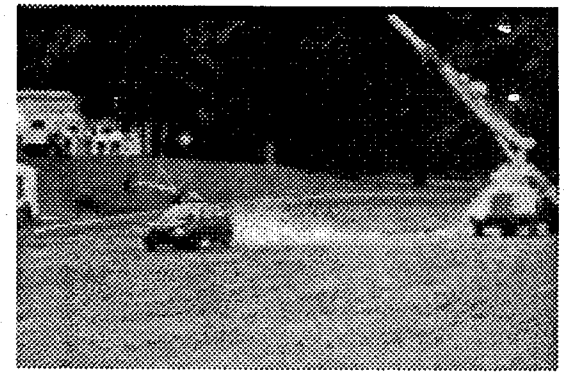
0.210

Figure 23. Test photographs during impact, test 98F009.

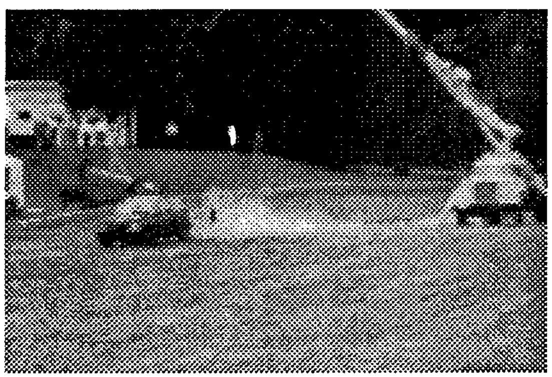
0.000



0.090

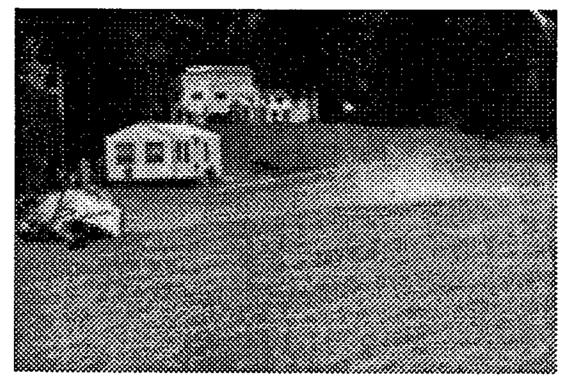


0.200



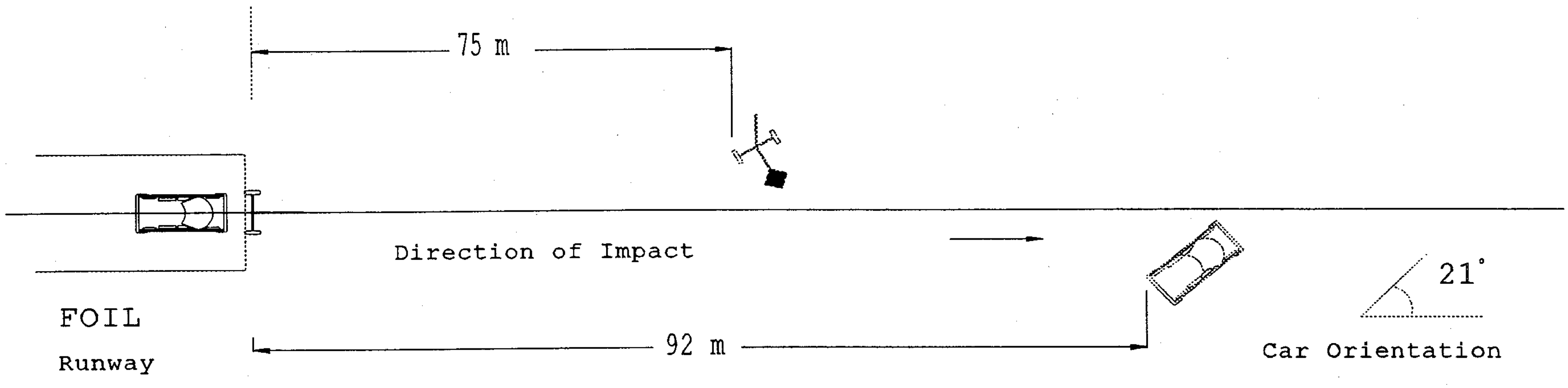
0.280

0.360



0.530

Figure 23. Test photographs during impact, test 98F009 (continued).



Test number..............................98F009

Date..............................June 4, 1998

Test article....work-zone portable sign trailer
Support..........50 mm box tube post set inside a steel sleeve

Tires........................P205/75 R14

Tire pressure...................220 kPa
Sign panel.......aluminum 1.7 m by 1.7 m

Foundation.........placed at end of FOIL runway

Vehicle......................1990 Ford Festiva

Weight: Inertial..................819 kg
Gross....................886 kg
Dummy....................68 kg

Impact speed.........................99.1 km/h

Impact location..........between tires, center

Impact angle.........................0 degrees

Vehicle analysis:	Observed	Design/Limit
Longitudinal:		
Vehicle Delta V	3.6 m/s	3/5 m/s
Occupant Delta V at 0.6 m	3.3 m/s	9/12 m/s
Ridedown acceleration	0.9 g's	15/20 g's
Lateral:		
Occupant Delta V at 0.3 m	N/A	9/12 m/s
Ridedown acceleration	N/A	15/20 g's

Peak 50 ms acceleration:
Longitudinal..................................6.9 g's
Lateral...................................... N/A

Vehicle Damage:
Traffic Accident Data (TAD)..................12-FC-2
Vehicle Damage Index (VDI)...................12TDCN1

Vehicle crush.......................................159 mm

Figure 24. Summary of test 98F009.

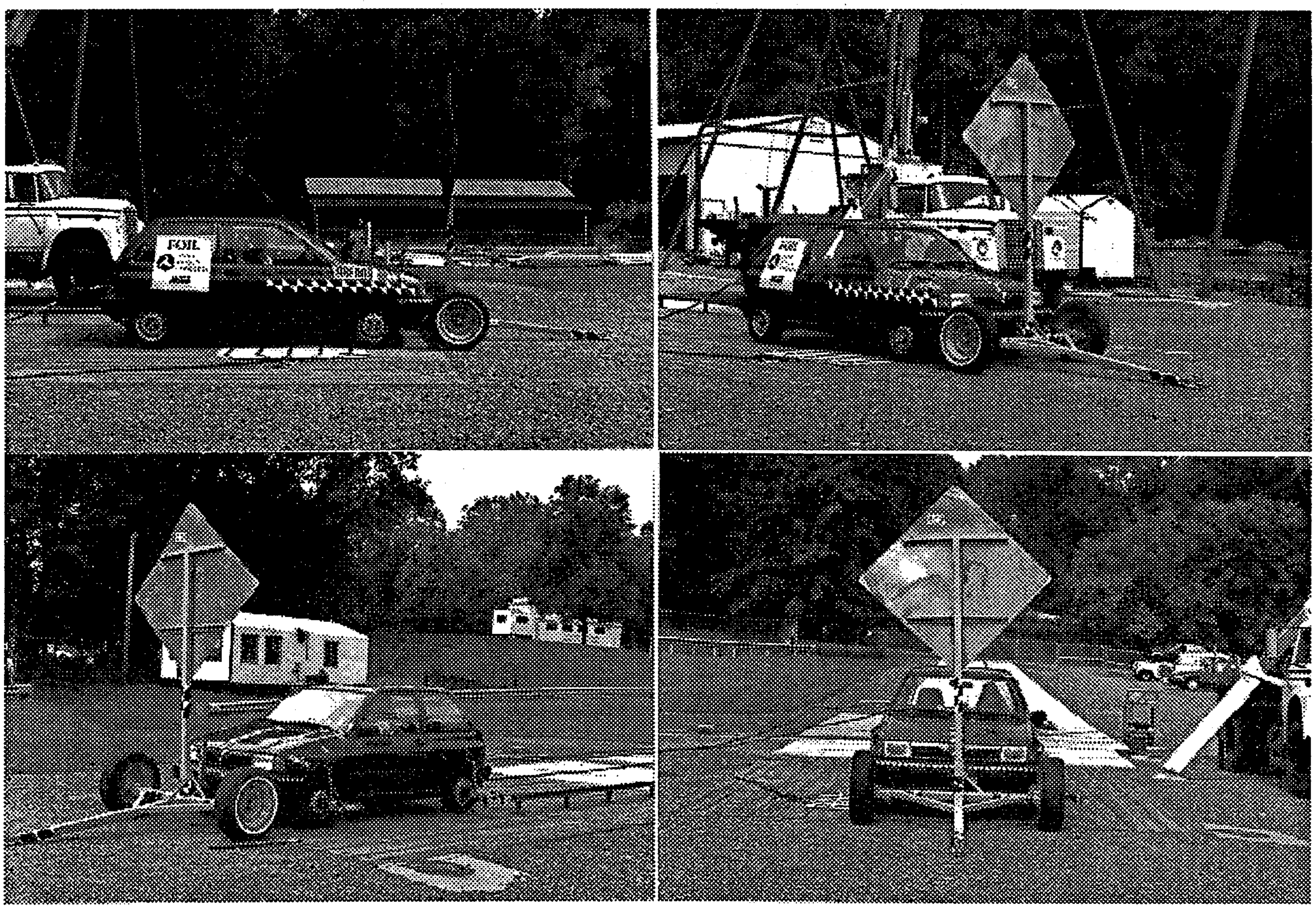


Figure 25. Pretest photographs, test 98F009.

Figure 25. Pretest photographs, test 98F009 (continued).

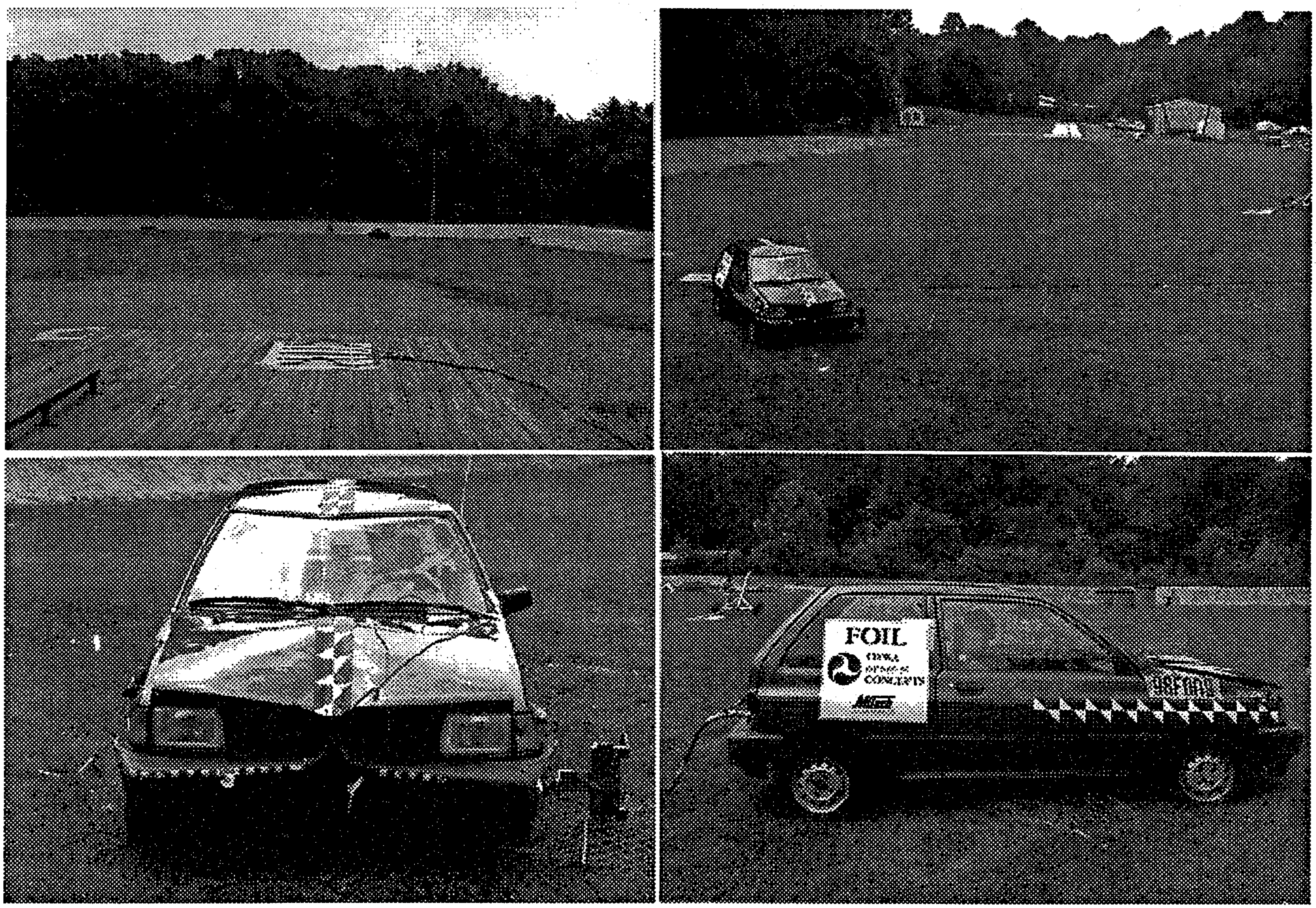


Figure 26. Post-test photographs, test 98F009.

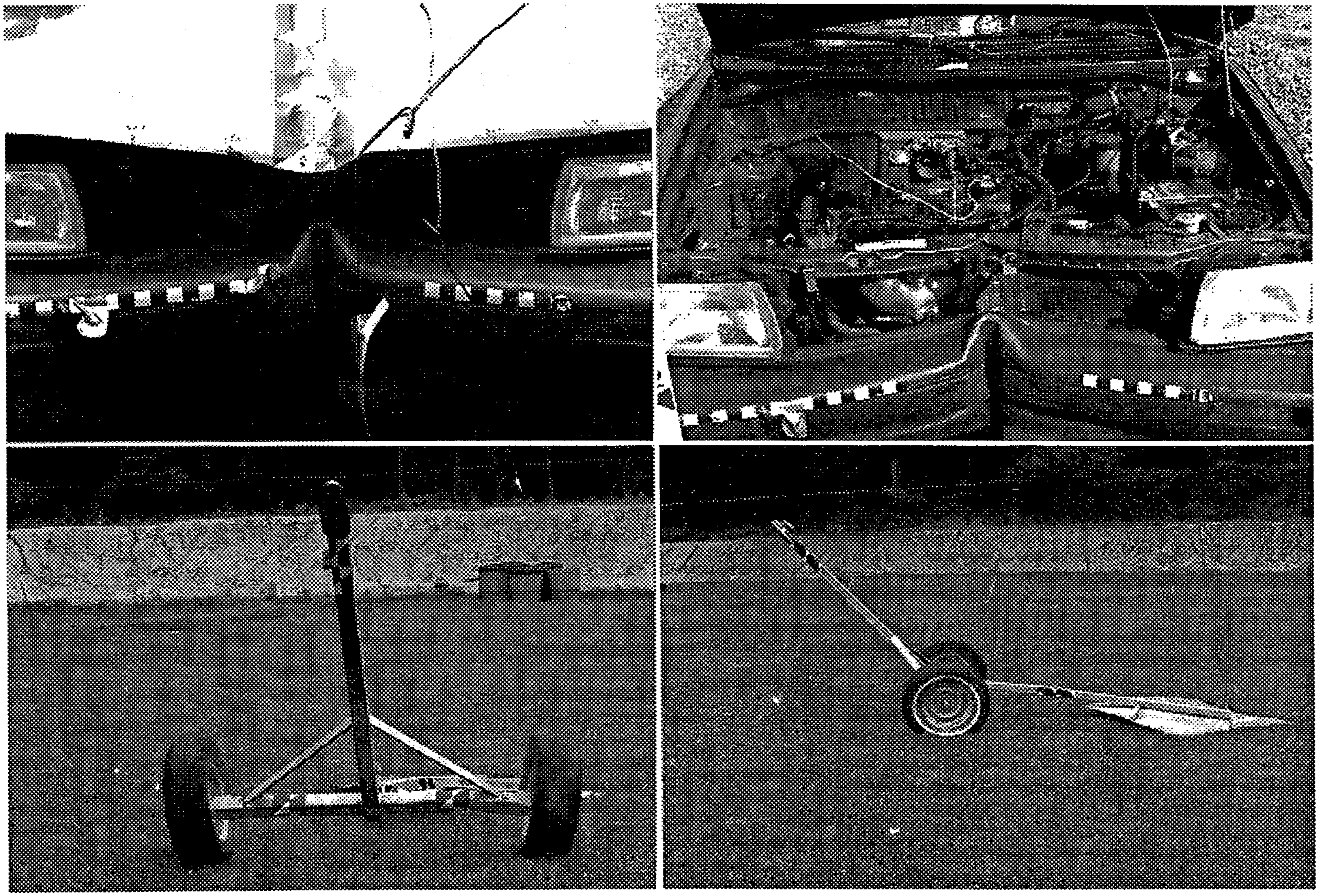


Figure 26. Post-test photographs, test 98F009 (continued).

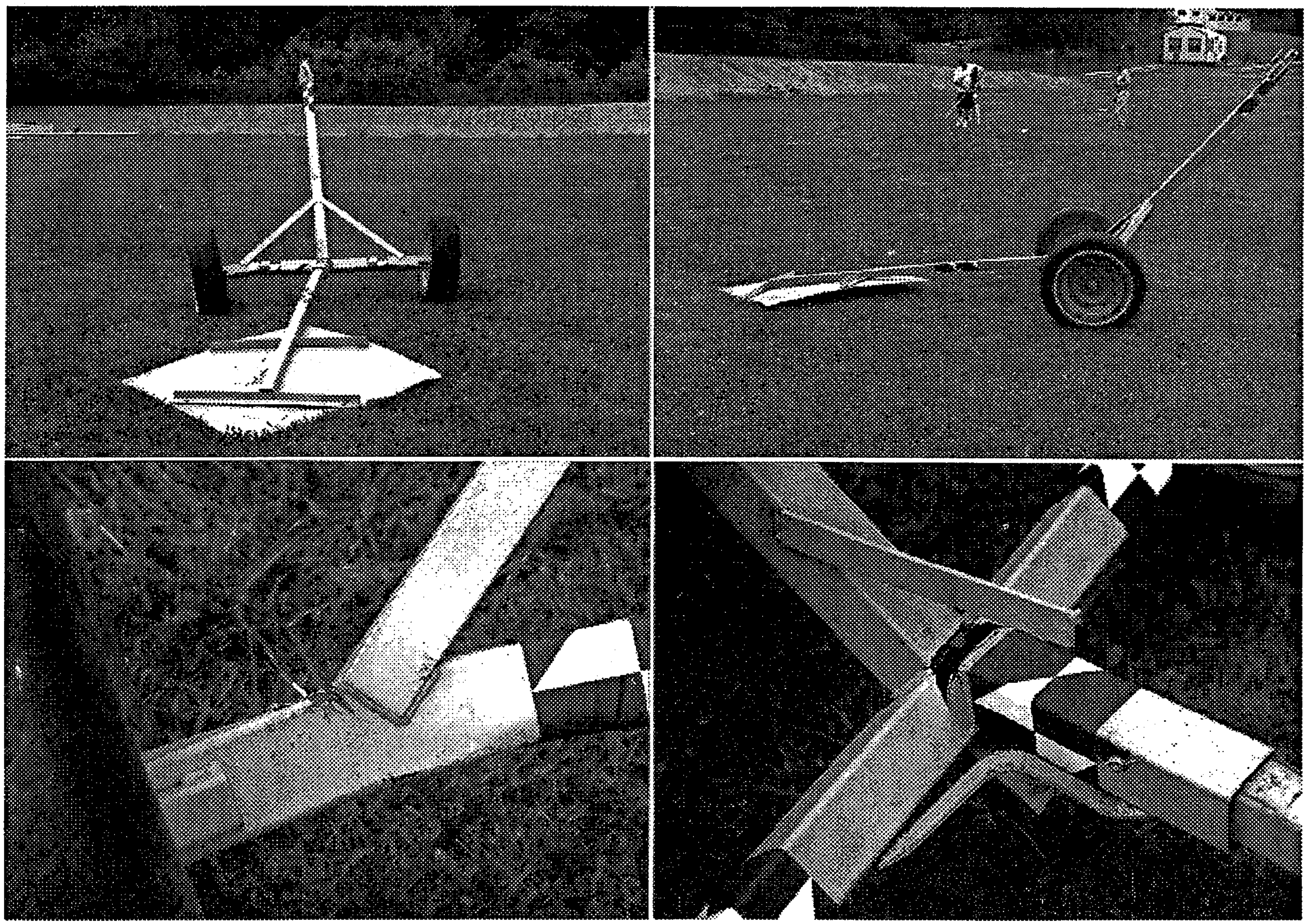


Figure 26. Post-test photographs, test 98F009 (continued).

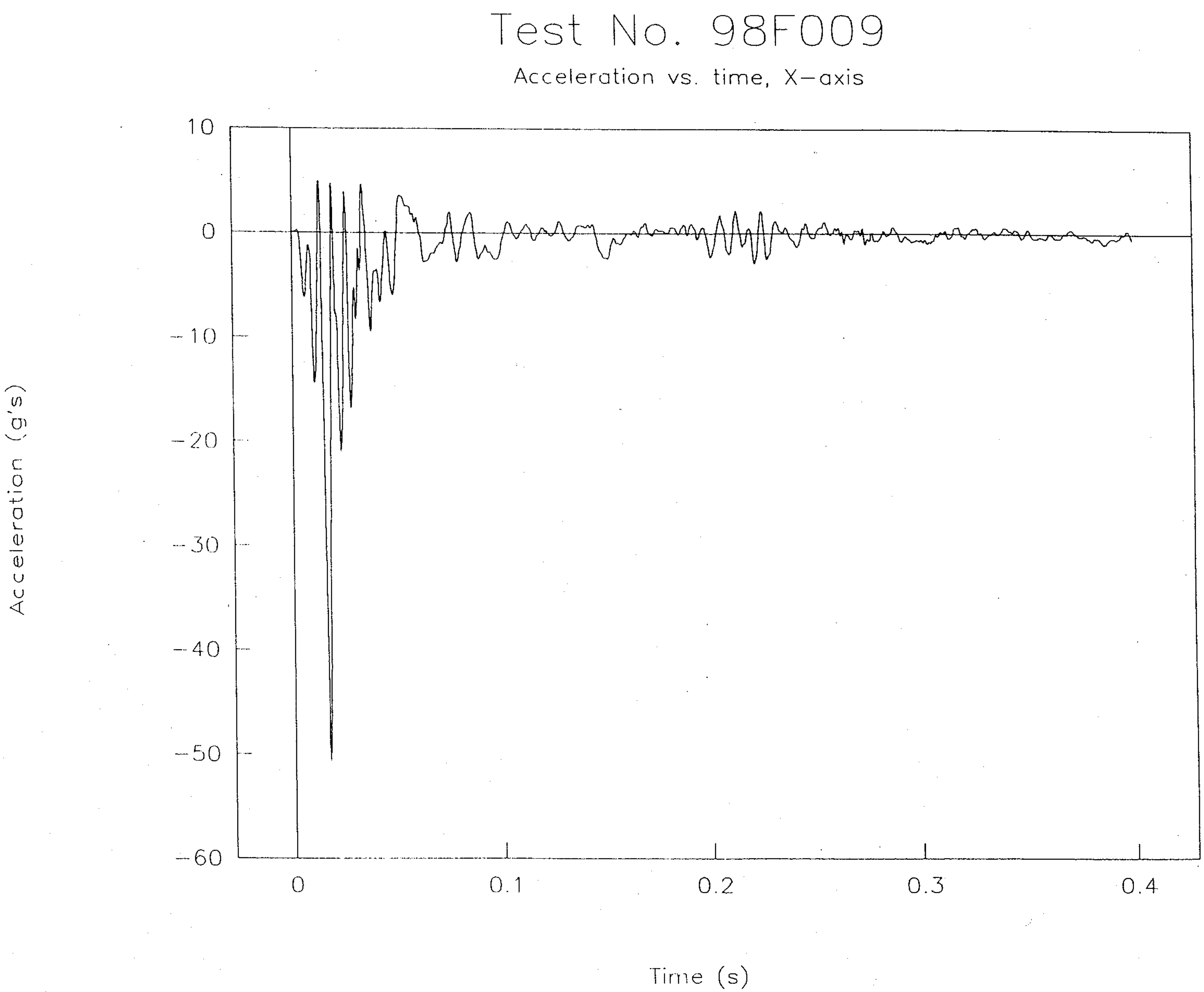


Figure 27. Acceleration vs. time, X-axis, test 98F009.

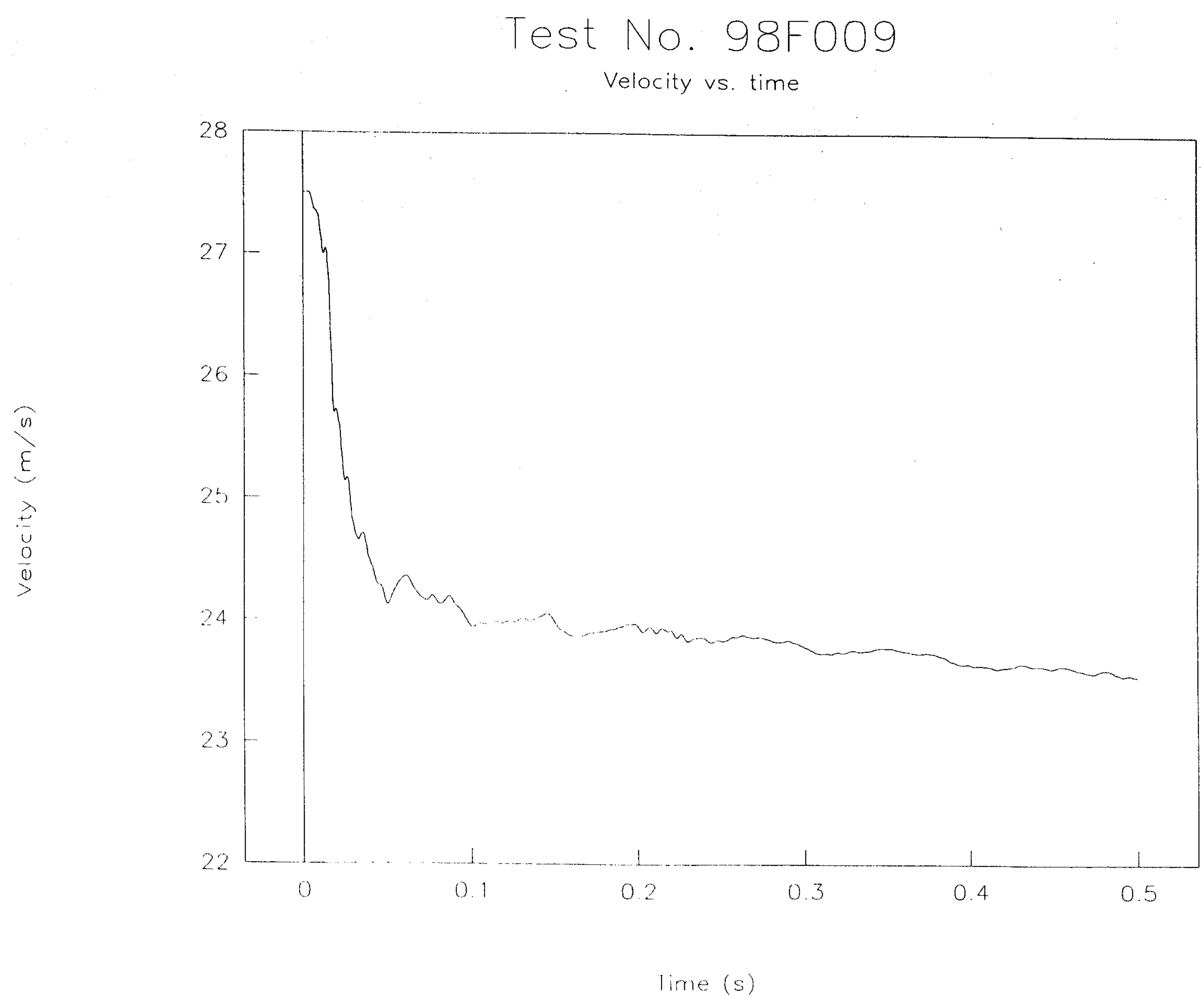


Figure 28. Velocity vs. time, test 98F009.

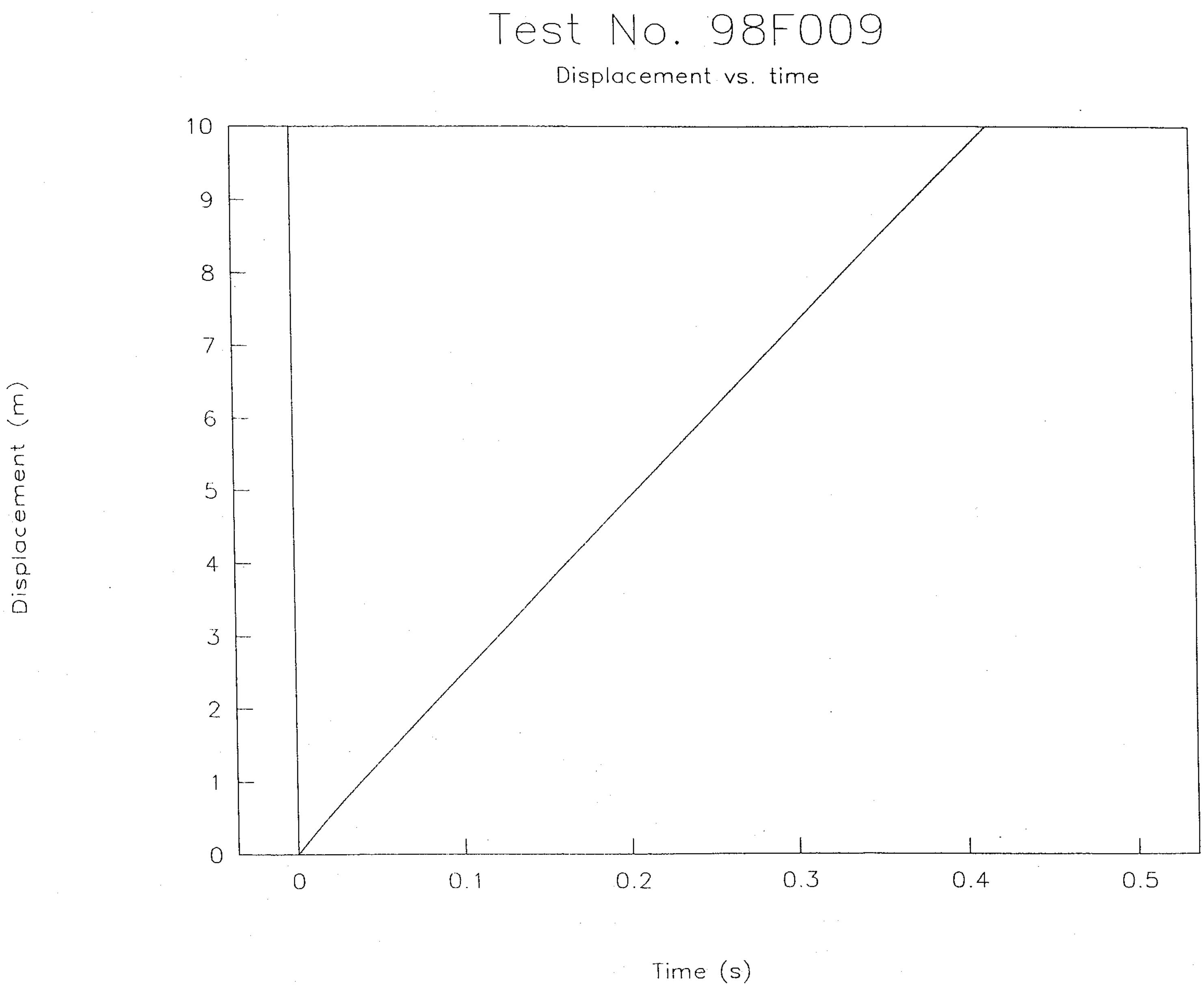


Figure 29. Displacement vs. time, test 98F009.

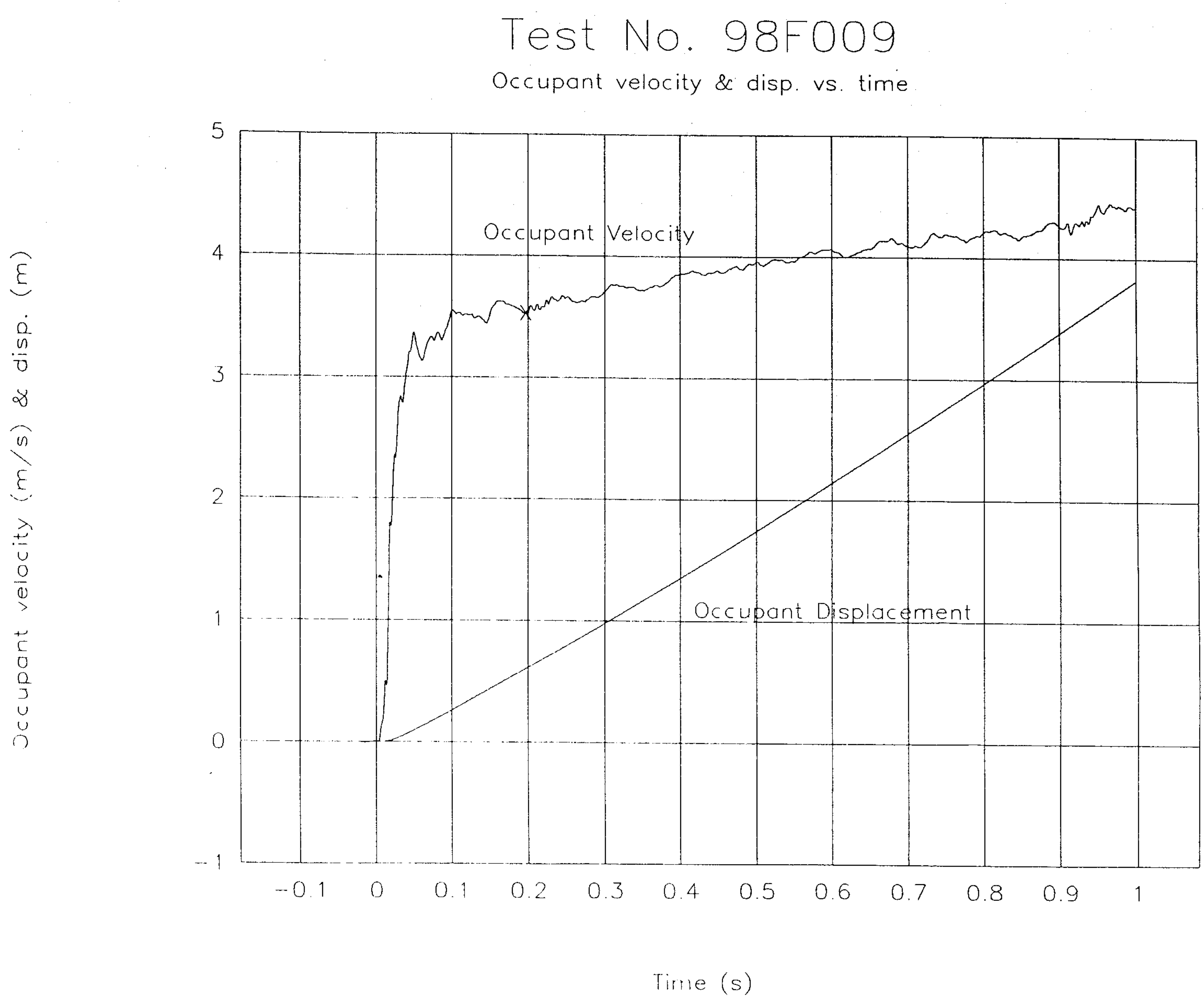


Figure 30. Occupant velocity and displacement vs. time, test 98F009.

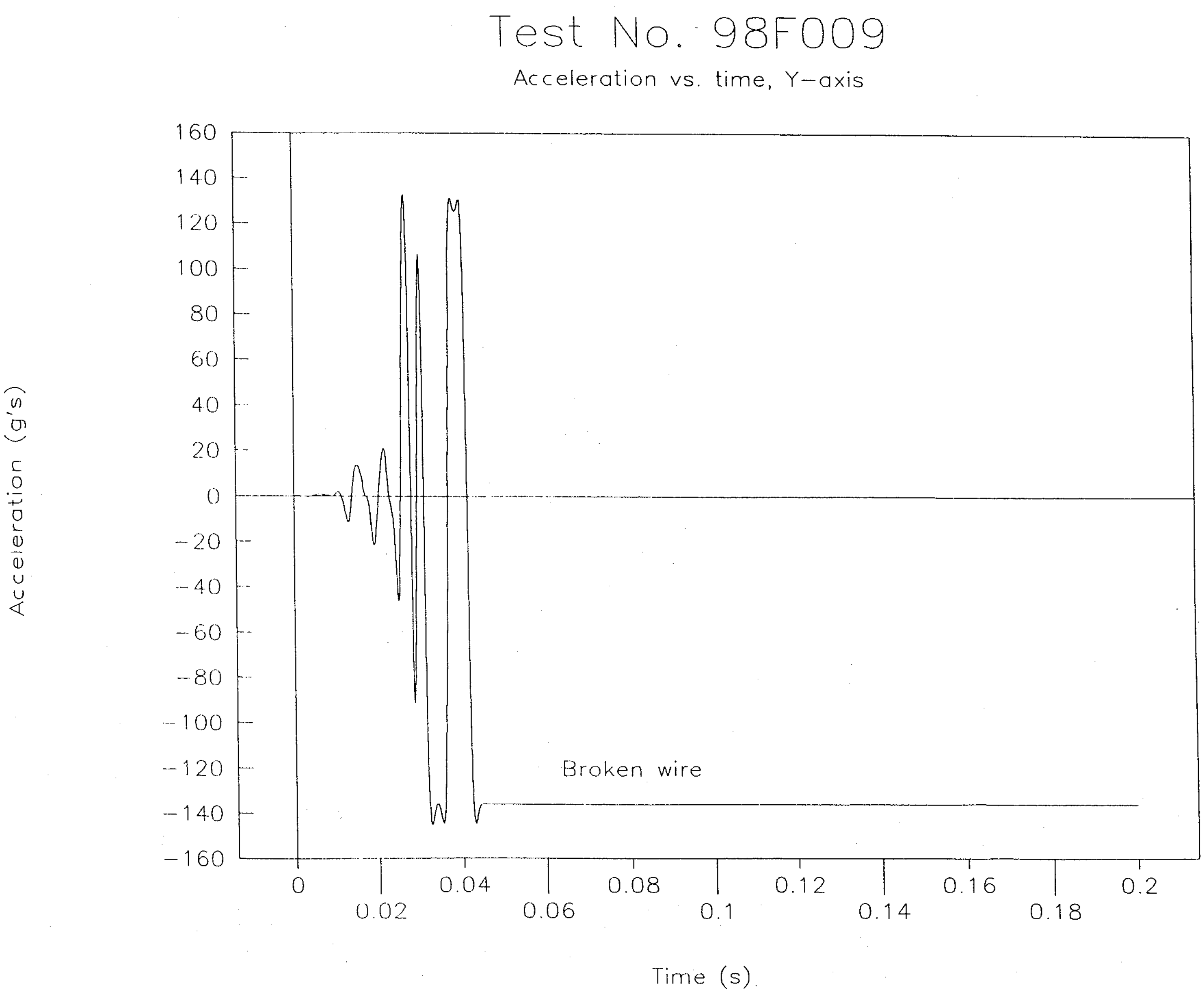


Figure 31. Acceleration vs. time, Y-axis, test 98F009.

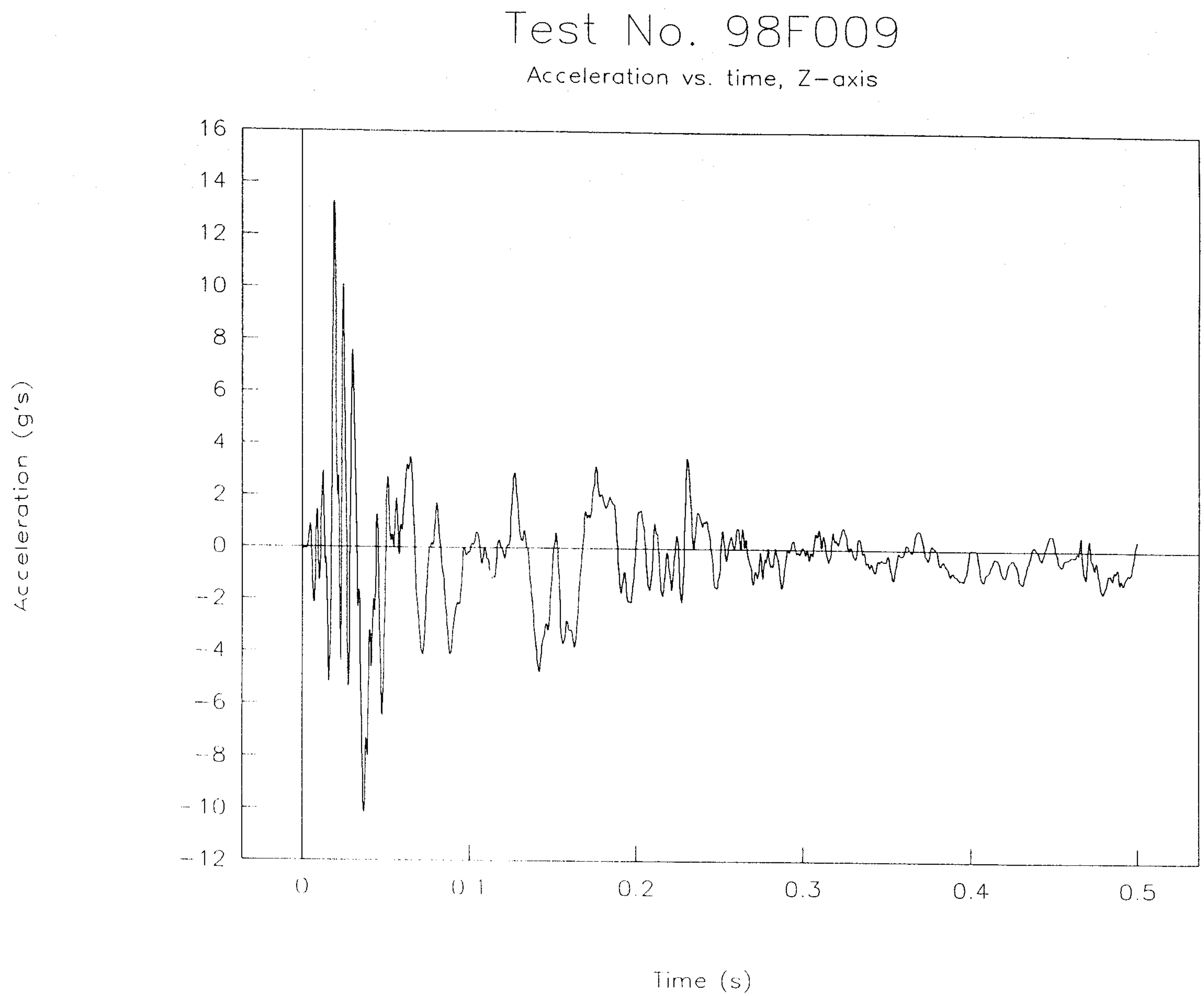


Figure 32. Acceleration vs. time, Z-axis, test 98F009.

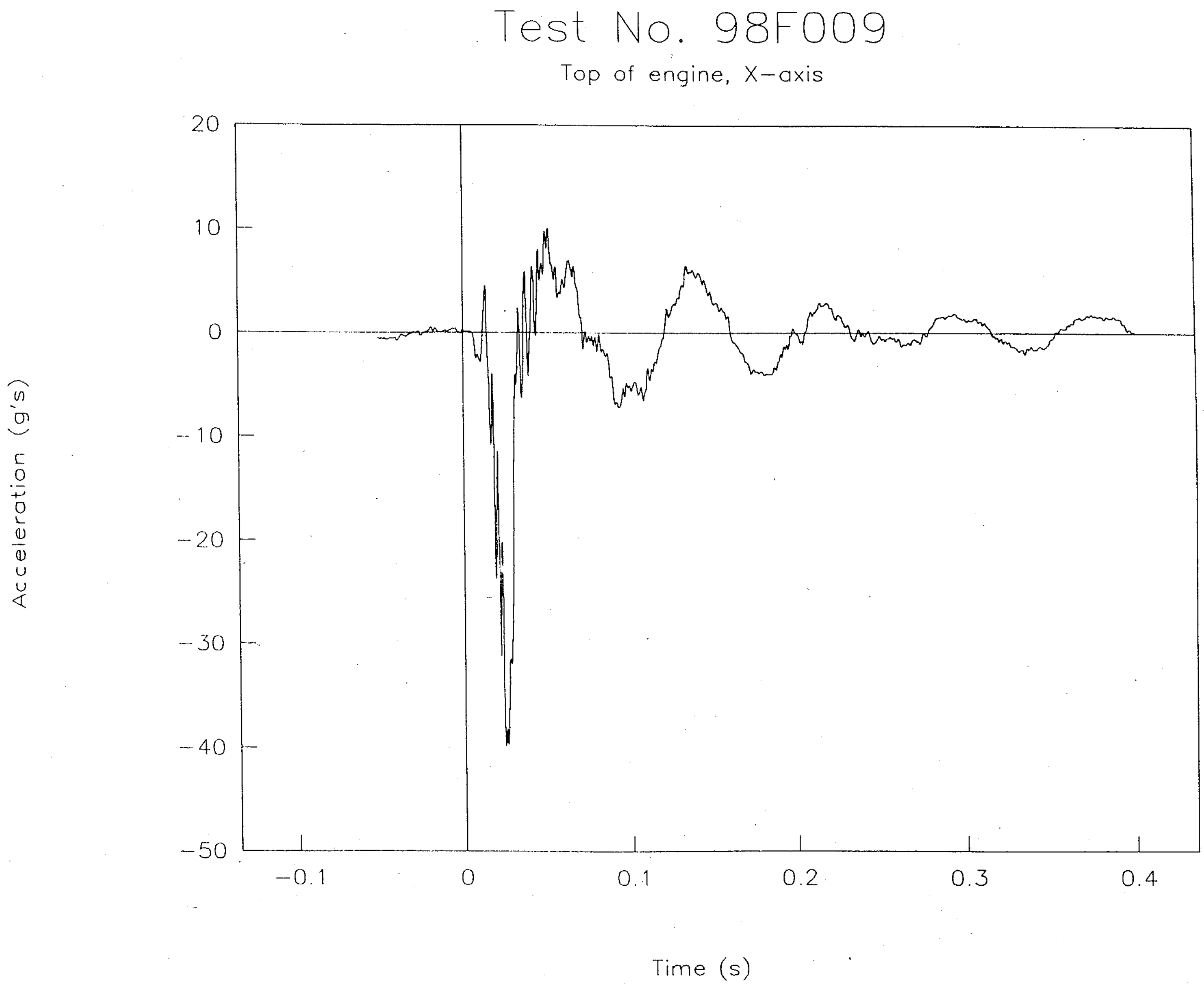


Figure 33. Acceleration vs. time, top of engine, X-axis, test 98F009.

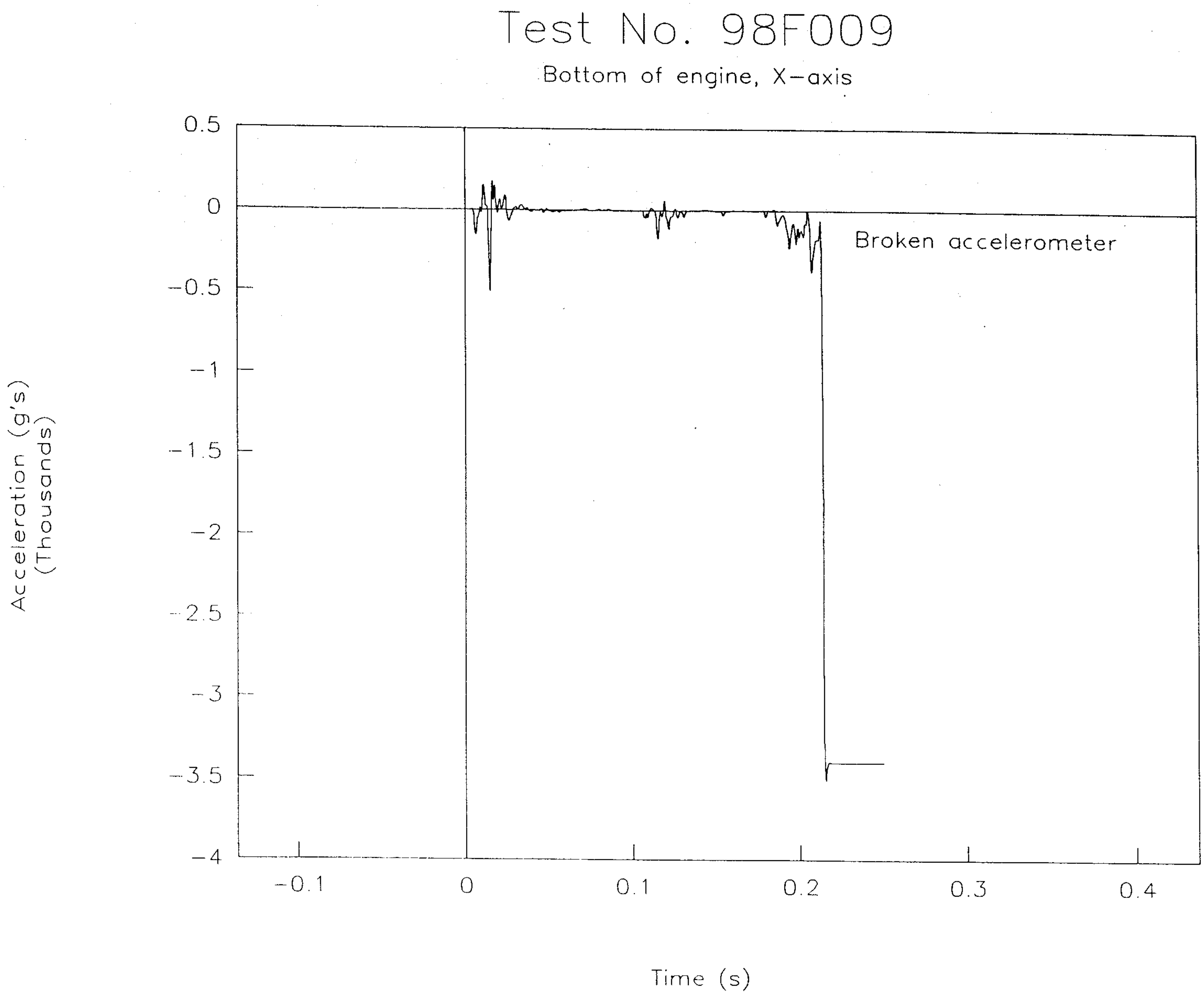


Figure 34. Acceleration vs. time, bottom of engine, X-axis, test 98F009.

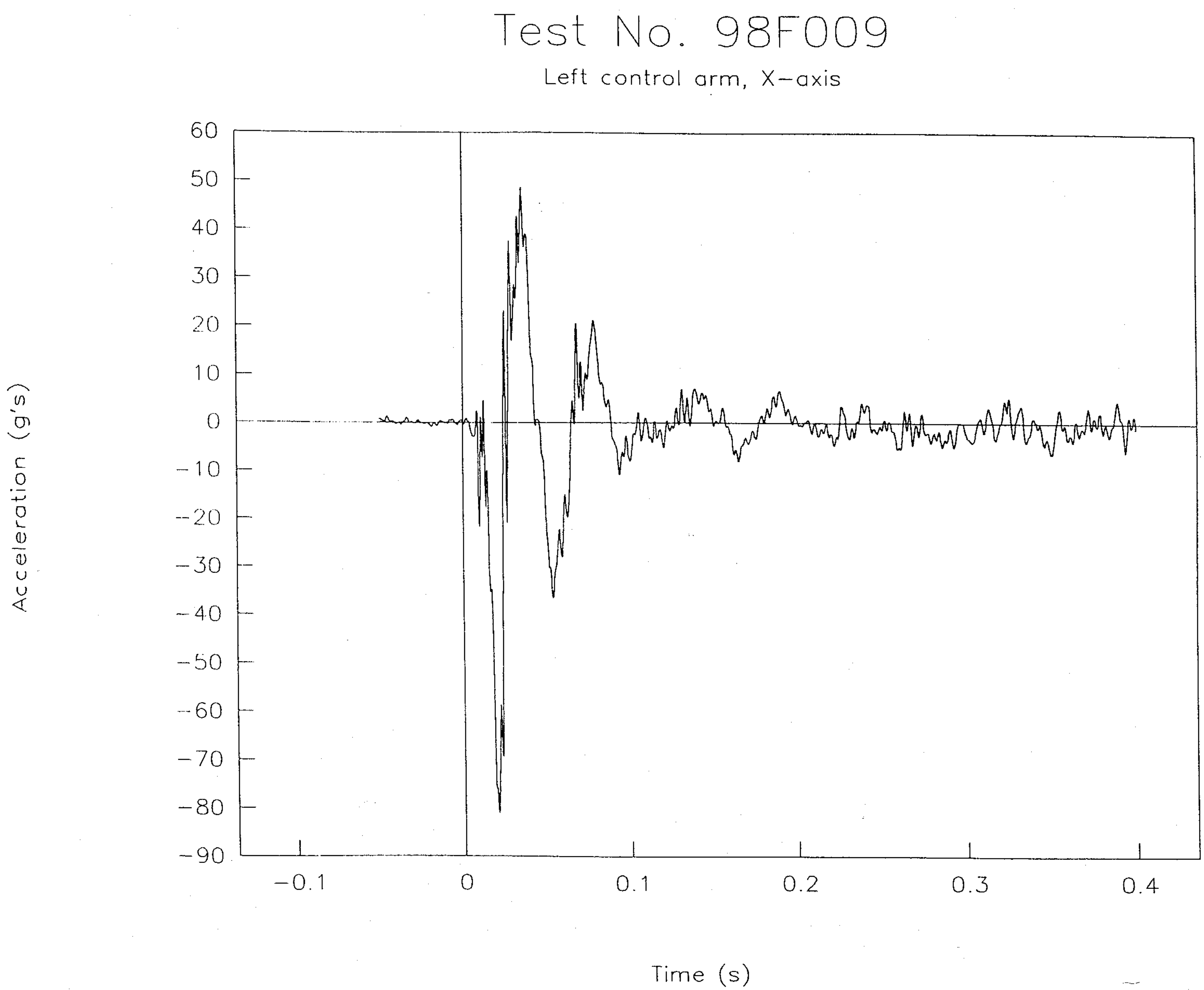


Figure 35. Acceleration vs. time, left control arm, X-axis, test 98F009.

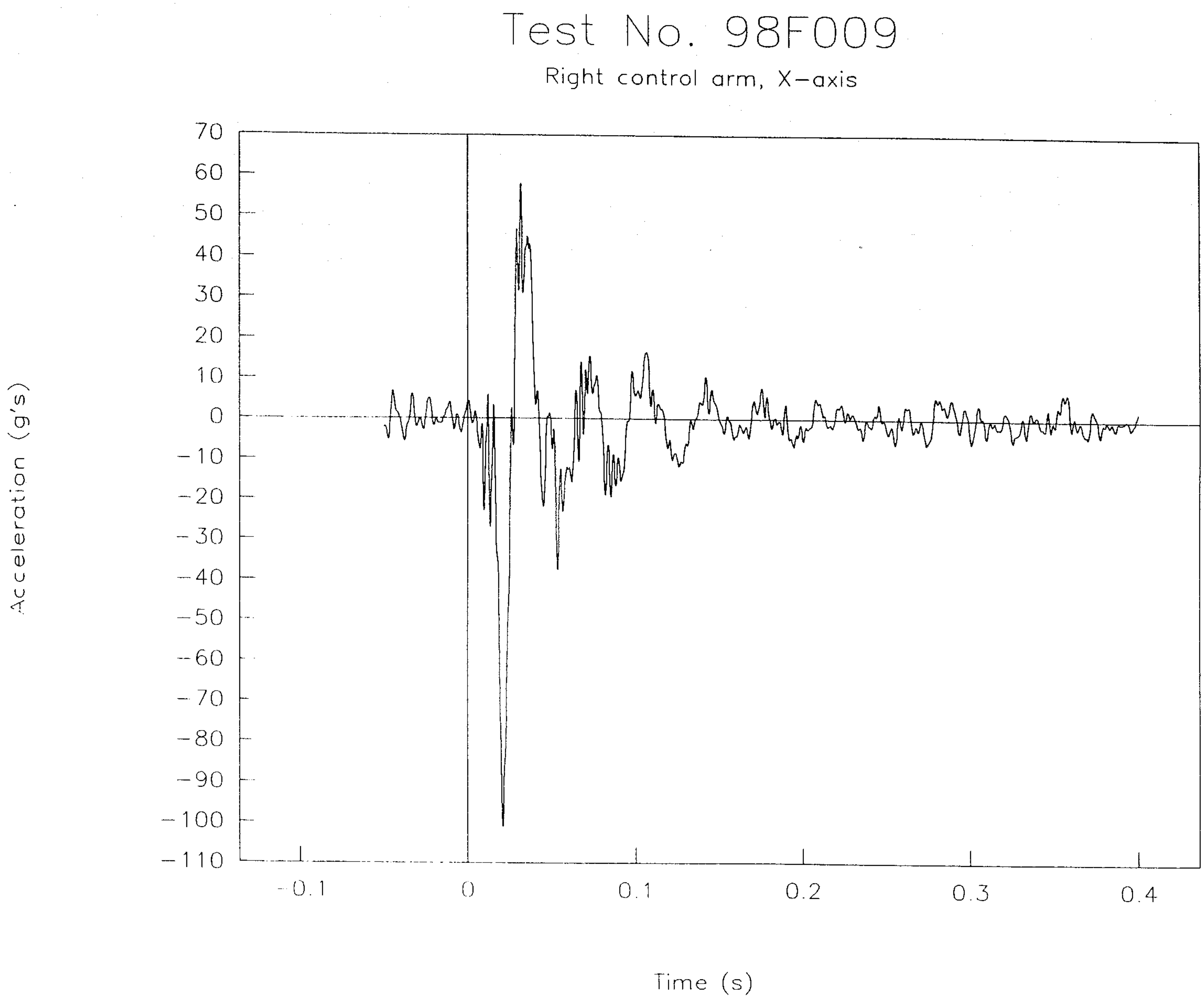


Figure 36. Acceleration vs. time, right control arm, X-axis, test 98F009.

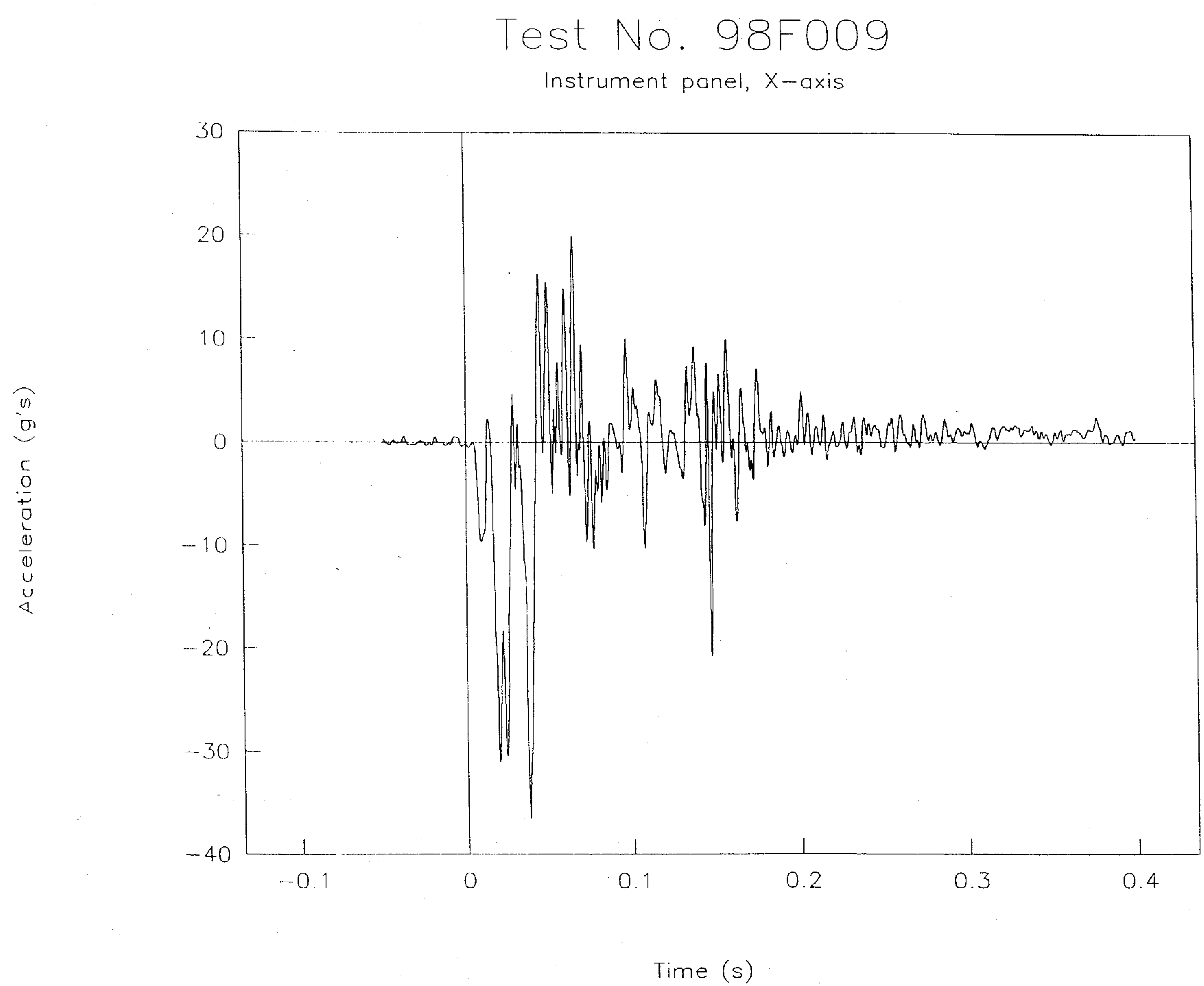


Figure 37. Acceleration vs. time, instrument panel, X-axis, test 98F009.

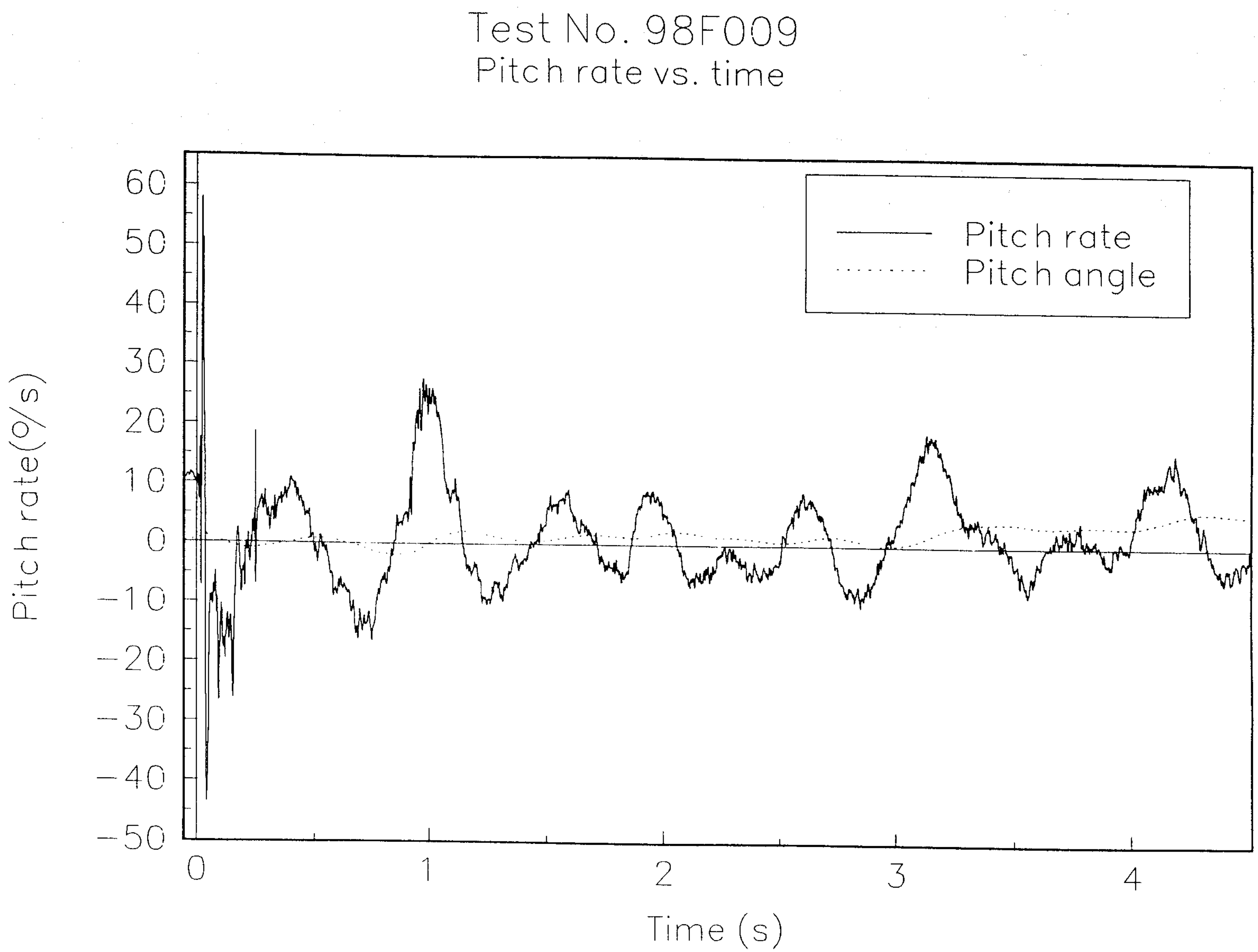


Figure 38. Pitch rate vs. time, test 98F009.

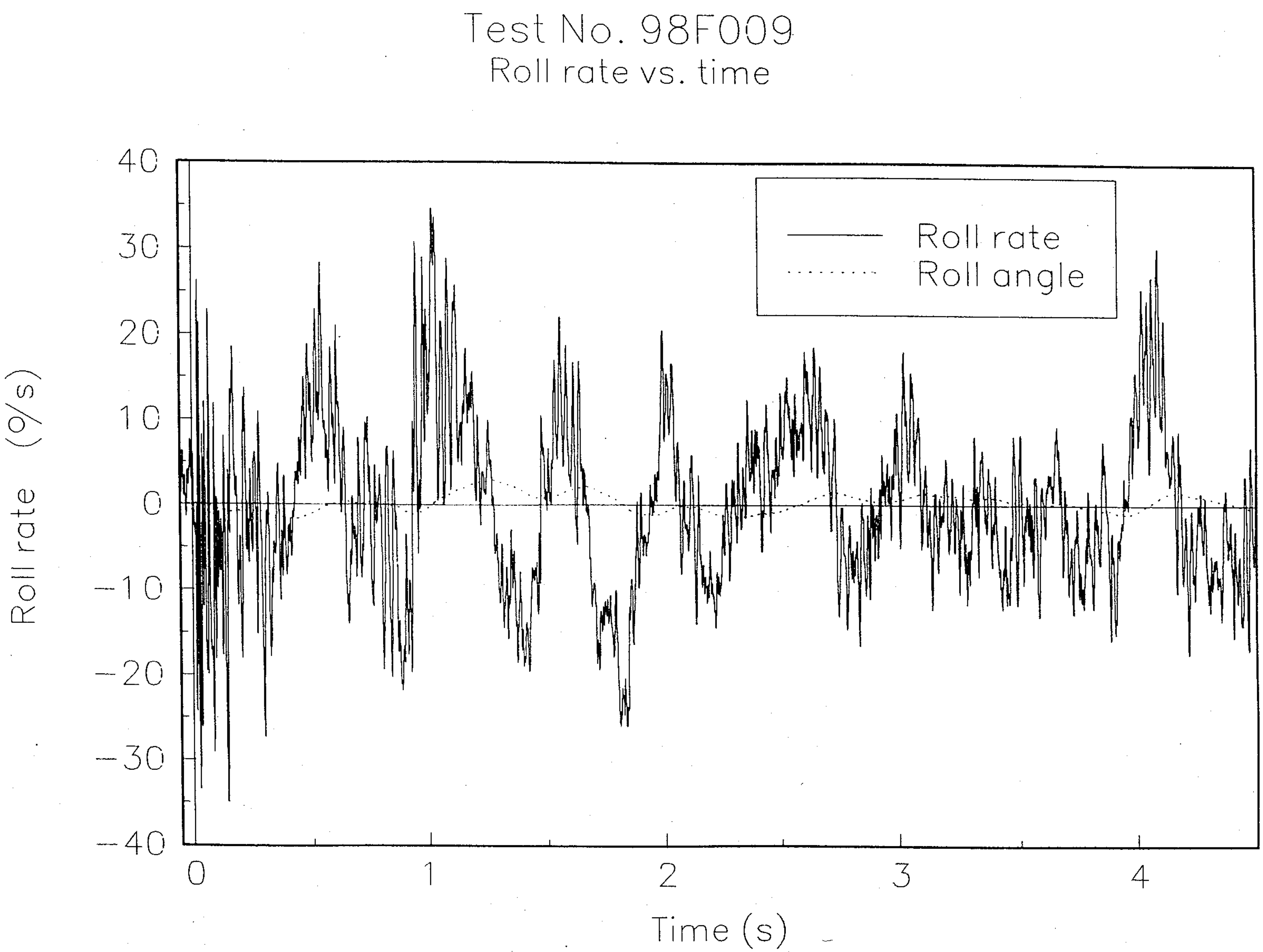


Figure 39. Roll rate vs. time, test 98F009.

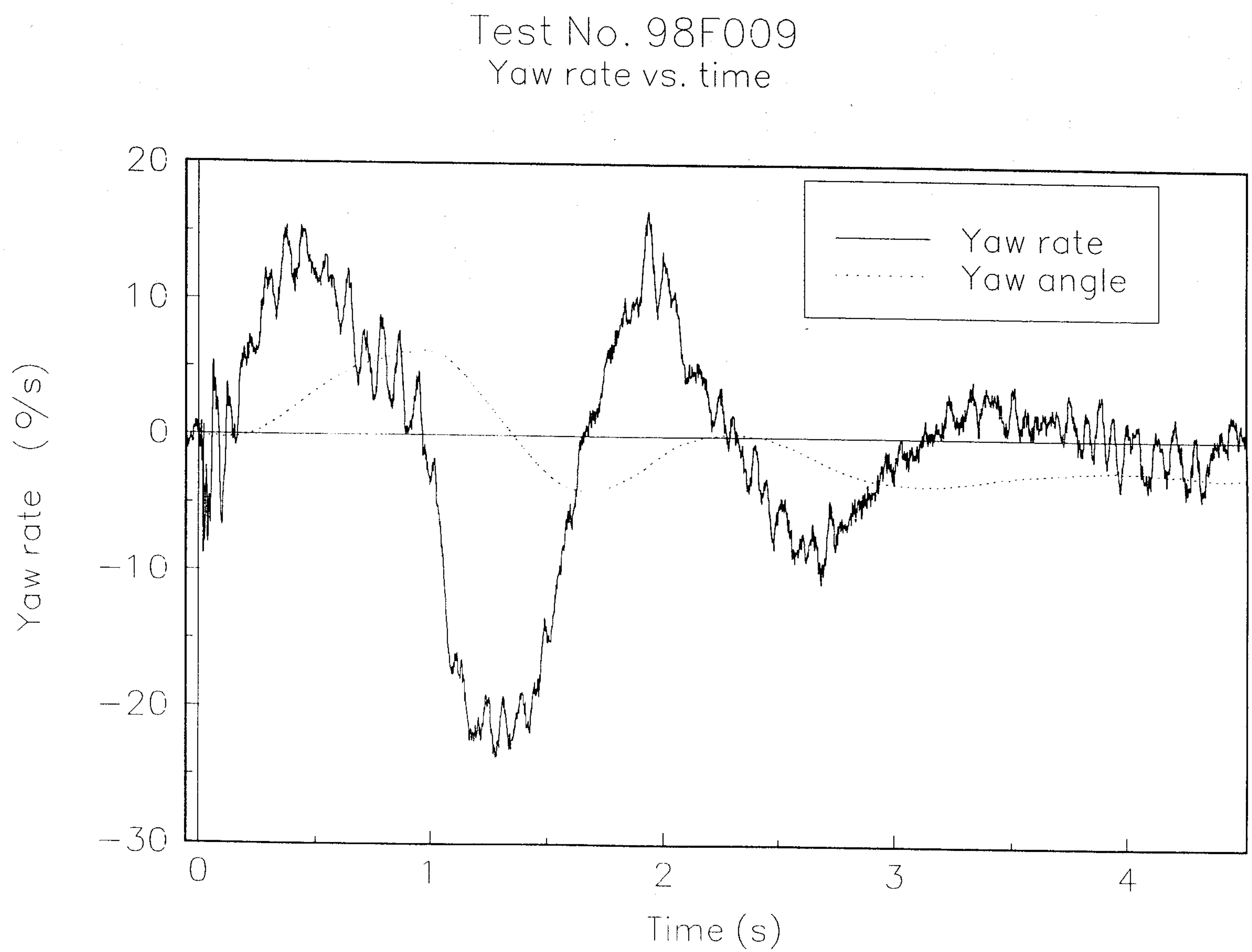


Figure 40. Yaw rate vs. time, test 98F009.

CONCLUSIONS

The results summarized in table 5 and in figures 5 and 23 show that two orientations of the portable sign trailer currently used in Montana for work zones met the safety performance criteria outlined in NCHRP Report 350 (test designation 3-71). The OIV for each crash test (3.3 m/s and 3.5 m/s) was below the required limit of 5 m/s. The damage to test vehicles was minor. Although the windshield was cracked in each test, there was no occupant compartment intrusion and no perceived loss of visibility or vehicle control. The vehicles maintained their stability after the collision with the sign trailer and continued to travel with their original trajectory. There was no indication that the vehicle, vehicle debris, sign trailer, and sign trailer debris would impose a safety risk to oncoming traffic (excluding median use). The sign trailer performed in a predictable manner during each test. Some of the vehicle energy was transfered to the sign trailer, forcing it from the vehicle path. The mass of the sign trailer was not significant enough to cause an unacceptable OIV. Satisfactory safety performance was observed for each orientation of the portable sign trailer.

REFERENCES

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